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## CATALASE ACTIVITY AS A MEASURE OF SEED VIABILITY\*

C. W. LEGGATT †

*Dominion Seed Branch, Calgary, Alta.*

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### INTRODUCTION

It is a truism to say that agricultural crop production per unit of land stands on the whole at a much higher level today than was the case in the past. Among the many factors which have contributed to this result, not the least important is the use of good seed. Not only should such seed be free from the seeds of undesired species, whether cultivated or not, but it should also have a high degree of vigour and viability, thus giving the seedlings the best possible chance of establishing themselves amid the competition of weeds and other plants. While this has been recognized for a long time it was only at about the beginning of the present century that the systematic testing of seeds began to assume any very considerable importance. From that time forward the establishment of seed testing laboratories became general in all civilized countries.

As a result of this general testing of seed it was found that the stock commonly used was in a deplorable condition and most countries adopted some sort of government supervision and control of the sale of seeds.

In making a test of the vitality of seed, a given number, usually two or more replicates of 100 seeds each, are counted out and placed on suitable media such as soil, sand, or moist blotting paper and left for varying lengths of time to germinate. The percentage of germination after all the seeds remaining undecayed have sprouted is considered a measure of the viability of the seed, while the percentage of germination after a shorter, arbitrary time determined by experience, is considered a measure of the vitality. The usual period of time required for a germination test is several days while some seeds require as long as a month or more to show their germinating capacity. Moreover, in some species the seeds exhibit a dormant condition which results in delayed germination or even makes the seed extremely difficult to germinate in laboratory practice.

It soon became apparent that the long period of time required was apt at times to be a serious hindrance to trade. Accordingly investigators turned their attention to the problem of securing a satisfactory index of seed viability without the necessity of having recourse to the germination test.

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†Supervising Analyst.

## REVIEW OF LITERATURE ON CATALASE AND OTHER BIOCHEMICAL TESTS

In 1901, Waller (27) published the results of his experiments in which he used an electrical method. He observed that the momentary excitation of living tissue by an electric current produced an after current which he termed a "blaze current". The blaze current was generally in the same direction as the exciting, but in the case of a tissue which gave a blaze current of the contrary sign, the blaze current remained in the same direction when the sign of the exciting current was changed. The blaze current was hence distinguishable from a polarization current. With non-living tissue however, the after current was invariably in the opposite direction to its exciting current and hence was only a polarization effect.

He found that with the soaked radicles of bean seeds (*Phaseolus vulgaris*) there was a marked negative correlation between the blaze current and the age of the seeds, radicles from dead seeds giving no blaze effects. He found also a correlation between the blaze currents given by whole seeds and their subsequent behaviour in the germination chamber.

He concluded that the blaze reaction was of a physiological character. There was shown to be a general, but not faultless, correspondence as regards magnitude between the blaze reaction and the germination, which was of the order of 0.0500 volts for fresh and vigorous seeds, 0.0100 volts for older and less vigorous seeds, while still older seeds, incapable of germination manifested blaze currents of only 0.0010 volts down to the small counter effect due to polarization of 0.0005 volts more or less. The method appeared suitable where there was a question of great differences of vitality, but less so where the differences were smaller.

Duvel (7) studied enzymes in their relation to the vitality of seeds. He pointed out that the artificial use of enzymes had greatly increased the germination of some old seeds, but showed this to be the case only when vitality was at a low ebb and not when extinct. He concluded that the loss of vitality in seeds is not due to the disorganization of the enzymes but that there is a close connection between the two. In some of his experiments he reduced the vitality of seeds by prolonged storage (up to 85 days) in closed bottles with varying quantities of water which, however, was not in contact with the seeds but added on small strips of blotting paper. The enzyme he studied was diastase (amylase).

Darsie, Elliott and Pierce (5) based a method for determining the vitality of seeds on the temperatures developed by a given weight of seeds placed in silvered Dewar flasks under conditions suitable for germination. They found a "normal temperature" for each of a number of different kinds of seeds. This normal temperature was the average increase in temperature produced by ten grams of vigorous, high germinating seed under the above conditions, per day. This varied from 1.82°C. for hemp to 0.49°C. for corn. A temperature in excess of normal was taken to indicate a condition of infection and was generally due to the heat generated by the growth of moulds, etc., while a subnormal temperature indicated decreased vigor. Apparently there was no attempt to correlate different temperatures with different percentages of germination.

Lesage, in a recent paper (14), cites his earlier work published in 1911 and 1917 on the determination of viability by methods other than direct germination. He used 20 solutions of KOH varying in concentration from N to  $\frac{3}{4}$  N  $\times 2^{-9}$  in which he soaked the seeds being tested. He found that seeds having lost their viability coloured all solutions an egg-yolk yellow, while those still viable coloured only the stronger solutions. He worked chiefly with *Lepidium sativum*, but found his method applicable to eighteen other species.

More recent studies in the determination of seed viability or age by methods other than the germination of the seed, or the catalase reaction, include those of Fick and Hibbard (8), Munerati (20) and Hottes and Huelson (12). The former based their method on the measurement of the conductivity of water in which seeds had been soaked. The greater diffusion of the salts from seeds of low viability than from those of high brought about the greater conductivity of the soak water. Using varying mixtures of old seed of 3% germination (since artificially killed seeds were found to be unsuitable) with fresh seed having 92% germination, some very fairly consistent results were obtained. Timothy and clover was the material used. Munerati found that the optimum temperature for germination was correlated with the age of the seed.

Faced with the problem of determining the relation between the vigour of seeds and the condition of the distilled water in which they had been soaked, Hottes and Huelson, (12), carried out a large number of experiments using the Abbé refractometer and the Leitz nephelometer. The method used was to soak 5 or 10 grams of the seed in 50 cc. of water in well stoppered bottles for 48 to 72 hours at 30°C. Two or three drops were used for the reading. There was found to be an inverse correlation between the refractive index and germination as also between the colloidal index and germination, but the latter correlation was better. As a standard for the colloidal index readings 0.5% c.p. soluble starch was used dissolved in 0.5% sodium toluene para-sulphochloramide.

They found that the coefficients of correlation tended to increase inversely as the percentage germination—an advantage, since it is usually the low germinating samples which are in doubt. The authors think the method may prove useful in determining the viability of grains and seeds having a fairly large endosperm.

Appleman (2), Crocker and Harrington (4) and others, whose work is touched on later in this review, showed that catalase activity paralleled respiratory activity. This fact suggested to some that catalase activity might be used as a measure of viability in seeds.

Nemec and Duchon (21) published some work based on this principle, but gave rather scanty particulars as to their method. They determined the volume of O<sub>2</sub> split off from 15 cc. of 3% H<sub>2</sub>O<sub>2</sub> by 2 gms. of ground farinaceous and 1 gm. of oleaginaceous seeds in a given time. By running a control in duplicate, using flour of the seed in question which had been heated to 100°C. for 20 minutes on the water-bath, and subtracting the volume of O<sub>2</sub> liberated by the control from that liberated by the experimental sample they

obtained a figure expressing the catalase activity of the seed which they found to be directly correlated with the germination. They then prepared a graph from which the viability might be read, the catalase activity as obtained by this method having been determined.

In a later paper (22) these authors traced again the correlation of loss of vitality with loss of catalase activity which, they concluded, represents a vital indicator enabling one to see in only a few minutes whether the seed examined has a high germination or not. They worked entirely with seeds of low vitality through age, using barley, wheat, oats, peas, etc. Extensive figures of numerous experiments are given, and graphs, where the percentage of germination is plotted against  $O_2$  liberated in 5 minutes, are shown. Several of the tables of figures include data showing the progress of the reaction at regular intervals and from these data, using the following modification of

the mono-molecular formula  $K = \frac{1}{\sqrt{t}} \log \frac{a}{a-x}$  in which  $\sqrt{t}$  is sub-

stituted for  $t$ , they calculated a series of values for  $K$  which were very tolerably constant except for the first few readings of any one determination, and which they used as an expression of the catalase activity of the seed instead of the volume of  $O_2$  liberated. In the above formula,  $K$  should be constant with varying values of  $t$  and  $x$ , where  $t$  is the time in seconds at which the reading was taken,  $x$  is the volume of  $O_2$  liberated in that time and  $a$  is the initial concentration of the  $O_2$  in the  $H_2O_2$  capable of being liberated. This constant  $K$  they found to be correlated with the percentage of germination, and prepared graphs from which the latter might be read, the former having been determined experimentally.

It will be shown later that some other investigators have failed to find this direct correlation claimed by Nemec and Duchon; but here, a review of the literature on the functions of catalase and the determination of its activity will serve as an introduction to further papers dealing with catalase activity and seed viability.

Appleman (1) working with potato catalase found that rapid deterioration of its activity set in after making the preparation, unless certain precautions were taken. These were to grind the material with  $CaCO_3$ , promptly to dilute the extract in the proportion of 1:10, and to keep it at  $20^\circ C.$  or less. He pointed out the necessity of grinding for a uniform time in order that the different preparations might be comparable, and used, as the basis of his comparison, the volume of oxygen liberated after a given period. He confirmed the existence of the insoluble ( $\alpha$ -catalase) and soluble ( $\beta$ -catalase) forms mentioned by Loew (15, quoted from Appleman), based on the passage of approximately 50% of the catalase through a filter paper, though none passes through a Pasteur-Chamberland filter. He found that potato catalase is very sensitive to temperature, being completely destroyed at  $50^\circ C.$  as compared with  $65$  to  $80^\circ C.$  for other forms, the destruction commencing at temperatures over  $20^\circ C.$  As the result of his experiments he concluded that catalase can only decompose a limited quantity of peroxide, and that catalase activity appears to bear some relation to respiration.

In a later paper previously quoted (2) this author concluded that, while oxidase activity does not, catalase activity does show a very striking correlation with the respiratory activity of the tubers.

In an attempt to show the inadequacy of the then existing methods of measurement of catalase activity, and to propose a new method, Becking and Hampton (3) criticized a number of methods in use at that time or proposed.

They point out that the measurement of the height of the foam produced during the reaction (method of Palladin) is rendered useless on account of the fact that this height varies with the purity of the enzyme. The titration method with  $\text{KMnO}_4$  fails to show clearly either the end point or the beginning of the reaction in many cases, the beginning being considered as being at the conclusion of the latency period.

Discussing the manometric methods, they note the danger of over saturation of the substrate with gas. This, and the fact that the solution contained a great part of the oxygen, was overcome by shaking and by the use of a shallow layer of fluid with a large surface, since shaking does not injure the catalase in the short time of the catalase reaction, even though when prolonged it does. The fact that the pressure becomes higher during the reaction, another objection which had been made to manometric methods, was disregarded as they found the effect to be negligible.

Another important criticism of nearly all methods of catalase determination was advanced. Recalling the definition of an enzyme as a substance that changes the velocity of a reaction, the only method theoretically justifiable would be to determine the time in which the reaction is completed under the influence of the enzyme.

The authors developed an autographic method which provided a complete record of the reaction and gave a satisfactory means of measuring the reaction-time. The reaction vessel (providing a large surface to the thin layer of the substrate) was connected to a mercury manometer by a ground glass joint. In the free arm of the manometer was a wooden float bearing a convenient support for a glass pen. This recorded on a cylinder in the usual way, the speed of the cylinder being 1 mm. in  $1\frac{3}{8}$  seconds at the periphery.

Discussion follows as to the chemical nature of the decomposition of  $\text{H}_2\text{O}_2$ ; they consider that there is evidence of two successive reactions and that the  $\alpha$ - and  $\beta$ -catalase of Loew are two successive stages of peptisation of the same substance.

In considering the comparison of the action of two different quantities of enzyme, since they found that there was destruction of catalase during the reaction, they point out that the reaction-velocity was not constant; hence they conclude reaction-velocity is a misleading test for the strength of an enzyme. On the other hand, the amount of peroxide decomposed gives different ratios after different lapses of time. These considerations confirm their previous conclusion that the times required to complete the reaction should be directly compared.

Using their autographic method they found that the reaction time was inversely proportional to the amount of enzyme and, with a constant quantity of catalase, directly proportional to the quantity of peroxide.

They worked out the reaction velocities of a number of different experiments and found that the expression:—

$$\frac{\text{Reaction velocity} \times \text{number of cc. peroxide}}{\text{Number of cc. enzyme}}$$

was fairly constant, but point out that it would require 39 determinations of this sort to prove what one determination of the reaction time gave, viz., that the reaction follows the Law of Mass Action.

They tried further to compare the curves obtained with mathematically constructed logarithmic curves, using the equation:—

$$t = C \log \frac{a}{a - x} \quad \text{and found:—}$$

C	E	
Calculated from	Amount	
curve	extract	$C \times E$
0.15	4 cc.	0.6
0.20	3 "	0.6
0.30	2 "	0.6
0.60	1 "	0.6
1.20	1/2 "	0.6

and concluded that this method would probably be the most practical and accurate.

They found that the *latency time*  $\times$  *amount of enzyme* seemed to be more or less constant but felt it was premature to draw any conclusions from this.

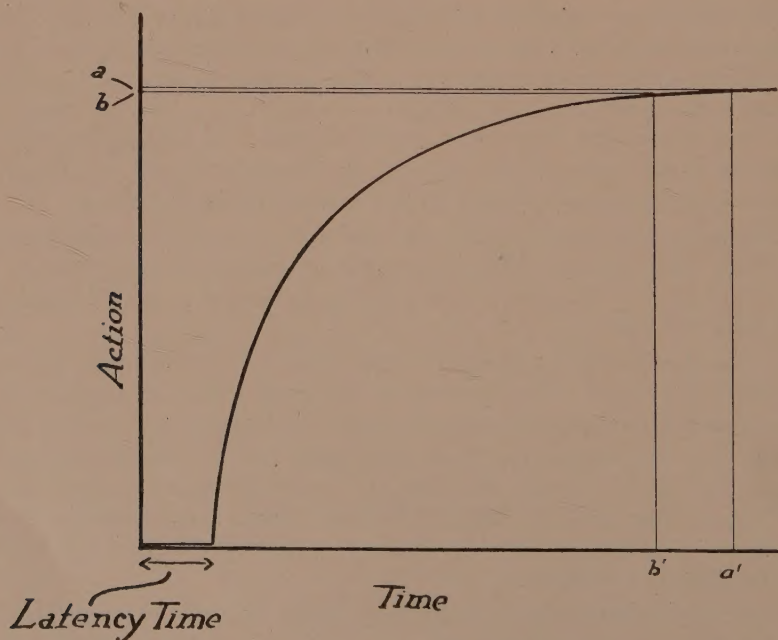


Figure 1.

Figure 1 shows the type of curve obtained on an autogram. It occurred to the present writer that it must be a matter of considerable difficulty to determine when the end point in time had been reached, though there is less chance of error in reading the "action" end point. (cf. *a* & *b* with *a'* & *b'*). The authors calculated the volume of oxygen actually liberated by subtracting the known volume of the container less that of the extract and  $\text{H}_2\text{O}_2$  from the observed final volume (allowing for the pressure set up by the column of mercury) and comparing it with the known volume of oxygen the peroxide was capable of liberating. Having determined the point on the autogram representing maximum oxygen liberation, the corresponding time was taken as the reading.

Studying the depressive effect of successive doses of peroxide on a given quantity of extract they found that the action of the catalase did not vary with its dilution nor with the quantity of the peroxide, but only with the absolute quantity of the enzyme itself, and that in the particular experiment under consideration the peroxide destroyed  $\pm 10\%$  of the catalase during each successive reaction.

In a very thorough study of the catalase reaction Morgulis (16) used a crude liver catalase preparation, but found that the data obtained applied to catalase from many sources. The peroxide was standardized by titration with  $\text{KMnO}_4$  and its pH adjusted to 6.9. The author points out the error introduced by the use of peroxide with an acid reaction. He found the optimum pH for the catalase reaction to be 7.0, but at this pH the  $\text{H}_2\text{O}_2$  decomposes somewhat, spontaneously, while at 6.9 the catalase shows almost the same activity as at 7.0. In experiments to determine this point the quantities of catalase and peroxide were so adjusted that the curve of oxygen evolution followed the isotherm of a bi-molecular reaction.

$$K = \frac{1}{t} \cdot \frac{x}{a(a-x)}.$$

In this first series of experiments the reaction was found to run true to the course of a bi-molecular curve at pH values of from 6.4 to 8.3, but not at acidities exceeding 6.4.

Increasing the concentration of the  $\text{H}_2\text{O}_2$ , the volume being constant, with a given quantity of extract had the effect of increasing the volume of oxygen liberated from gram-molecular concentrations of 0.16 to 0.32, though the percentage of peroxide decomposed was less with increase of concentration. Gram-molecular concentrations in excess of 0.32 had the effect of diminishing not only the proportion of peroxide decomposed but also the actual amount of oxygen liberated. In addition to these effects, the reaction proceeds more slowly with increase of concentration of  $\text{H}_2\text{O}_2$ . From the curve illustrating these data it may be assumed that decomposition would be complete with a concentration of 0.14 M  $\text{H}_2\text{O}_2$ .

Discussing the depressive effect of an excess of peroxide on the catalase reaction, he concludes that catalase is not destroyed through oxidation by the peroxide since even a very large excess of the latter does not prevent the reaction. Nor does he find this depressive effect to be due to some incidental

impurity which becomes present in sufficient quantity to retard the reaction when excess of peroxide is employed. The actual reduction in the volume of the oxygen liberated when the concentration of  $H_2O_2$  exceeds a certain amount leads to the conclusion that the catalase reaction is a reversible one.

The maximum oxygen evolution was found to occur when the relative amounts of catalase and peroxide were so adjusted that 65 to 70% of the latter was decomposed.

Using a moderate excess of peroxide he found that the reaction came to a stop after partial decomposition. With the addition of a further dose of catalase the reaction went to completion. Then, using a constant quantity of catalase and adding the peroxide in two doses, the first dose was completely decomposed, the second partially and, the proportions having been adjusted to conform with the previous experiment, it was found that the total volume of oxygen was the same as before. Another variation of the same experiment was tried in which the same quantity of peroxide was used as in the first, but the *first* dose of catalase was added in two portions. These two stages made no difference to the total volume of oxygen produced.

He concluded that the catalase is used up in the reaction and that it reacts with a definite quantity of the peroxide.

In a further series of experiments he found that there was a direct proportionality between the amount of catalase and the amount of oxygen it produced from a given quantity of peroxide. This was true only for absolute amounts, changes of concentration alone having no effect.

In a curve illustrating the effect of an increase in the quantity of peroxide with a constant quantity of catalase, he found that the curve of oxygen evolution had a smaller slope for every new increase in the amount of  $H_2O_2$  employed, which is significant since, if the diminution were due to an oxidation of the catalase, a proportionately greater destruction of it would be expected with the greater amount of peroxide.

The reaction velocity was found to diminish in the early stages with increase of concentration of  $H_2O_2$ , using the reciprocal of the time as a measure of the rate. In the later stages the rate became equalized except with a concentration of over 0.36 gm. Mol. when the retardation was very marked throughout.

When the absolute amount of peroxide and the absolute volume of reacting liquids were unchanged but the relative concentration of the catalase was increased, the rate remained practically constant; but when the amount of the catalase was increased, the relative concentration remaining unchanged and the absolute amount of the peroxide being the same, the rate varied directly with the amount of the catalase. He concluded that the reaction rate depends directly on the quantity of catalase used, while the effect of the peroxide is to limit the rate.

In discussing the chemical nature of the catalase reaction he states that the course of the reaction seems to depend solely on the quantitative relation between the available catalase and the peroxide. He finds three stages. When the conditions are such that the decomposition falls between 95 and 100%

of the peroxide, the reaction follows a monomolecular course and the formula

$$K = \frac{1}{t} \log \frac{a}{a-x}$$

applies; when the decomposition falls between 68 and 82% the reaction is bi-molecular, the formula

$$K = \frac{1}{t} \cdot \frac{x}{a(a-x)}$$

applying; while a more or less intermediate zone exists between 88 and 93% decomposition, when the reaction is one and one-half molecular, and the formula

$$K = \frac{1}{t} \cdot \frac{\sqrt{a} - \sqrt{a-x}}{\sqrt{a(a-x)}} \quad \text{applies.}$$

It was necessary to change the quantities very little to produce appreciable differences in the value of  $K$ . Three graphs are shown in which the experimental curves are plotted with the theoretical curves calculated from the average value of  $K$  for each respective experiment and show a striking similarity between the two.

The use of very large quantities of peroxide is criticized on account of the depressive effect, unless very large quantities of catalase are employed. On the other hand, when comparison is made of the catalase activity of preparations of presumably different strengths, the depressive effect is much greater in the case of the weaker sample and differences will be exaggerated.

He concludes that the entire method of comparing several samples of catalase on the basis of the amounts of oxygen liberated is of questionable accuracy, and recommends that the comparison should instead be made between the respective quantities of catalase preparation required to set free the same amount of  $O_2$  from a given quantity of  $H_2O_2$ , and that further, the reaction be adjusted to follow some definite course approximating 75% peroxide decomposition.

Heinicke (10), working with apple-leaf tissue, pointed out the importance of variations in concentration of the substrate, particularly in the case of catalase material. He found that since, by increasing the quantity of  $H_2O_2$  used, the volume of  $O_2$  liberated was increased somewhat, but not markedly, it was important to have an excess of peroxide.

Agitation of the preparation, a liquid suspension, did not degenerate the catalase of apple-leaf tissue. In making the determination, the rate of agitation varying from 30 to 90 shakes per minute did not affect the speed of oxygen liberation.

On letting the preparation stand, the catalase activity increased up to one hour, after which the increase became so slight that it might be disregarded, and retained its full activity up to four days. Without preliminary neutralization with  $CaCO_3$ , however, the degradation was very rapid.

In a paper later than the one previously quoted, Heinicke (11), discussing the preparation of material, pointed out the advisability of trituration with water, the time of grinding making no difference provided it was done wet; the probable cause of the lowering of catalase activity with excessive grinding in Crocker and Harrington's (4, reviewed later) experiment with Johnson grass being that it was done dry.

He tested his peroxide with  $\text{MnO}_2$ , using as the index of activity the time required to liberate 5 cc. of oxygen. He found a retardation of the reaction if the 5 cc. of oxygen liberated represented more than  $1/5$  or  $1/6$  of the available  $\text{O}_2$  in the peroxide. On the other hand, the larger the amount or the greater the strength of the peroxide, the slower the initial rate of catalase activity, but the more rapid the subsequent liberation of given quantities of oxygen. In such cases he found that the volume of gas in the burette might either be reduced by as much as 0.5 cc. when the liquids were first mixed, or remain the same for the first 5 to 15 seconds in spite of continued shaking. This "latency time", while frequently observed, does not always occur.

After the first dose of peroxide was completely decomposed, he found that a second was split more slowly, whether by catalase or  $\text{MnO}_2$ . The effect of the dilution of the liquids in the reaction chamber was to retard the liberation of the  $\text{O}_2$  from the  $\text{H}_2\text{O}_2$ , both by his apple bark preparation and by  $\text{MnO}_2$ , such dilution of a weak preparation resulting in a more than proportional loss in catalase activity, while doubling the quantity of the preparation reduced by more than one-half the time required to liberate a given quantity of oxygen. The stronger the original preparation, whether of catalase or  $\text{MnO}_2$ , the more nearly proportional was the activity of diluted or increased quantities.

Knott (13), working principally with leaf tissue of spinach and tomato, used the following technique. One gram of discs of one centimeter diameter, cut from the leaves, was ground with an equal weight of  $\text{CaCO}_3$  in a mortar with 2 cc. of water and a pinch of pure quartz sand for two minutes. The paste was washed into a bottle with 18 cc.  $\text{H}_2\text{O}$  (or presumably made up to 20 cc. total). After thorough mixing, 2 cc. were immediately withdrawn and placed in one arm of the dry reaction tube, in the other arm being placed 2 cc.  $\text{H}_2\text{O}_2$  (equivalent to 26 cc. available  $\text{O}_2$ ) previously neutralized with a slight excess of  $\text{CaCO}_3$ . During the course of the reaction the levelling bulb was moved to keep the reaction under constant atmospheric pressure. His rate of shaking was 240 complete excursions per minute, but he found no variation in the total rate of liberation of oxygen when the speed was varied from 220 to 300, though the initial rate was faster with the higher shaking speed.

A constant temperature bath operated at  $20^\circ\text{C}$ . was used, the reaction vessel being immersed therein for three minutes prior to shaking. Check tests were made to within an accuracy of 1%.

He allowed the reaction to proceed beyond the 5 cc. used by Heinicke, since he found that catalase activity in two tests might run parallel up to this point but diverge markedly thereafter.

In discussing the amount of  $H_2O_2$  to use, he stated that it might in certain cases be a limiting factor when the oxygen liberated was more than one-fifth of the total available, but he had not found it so until 60% of the  $O_2$  was released. By increasing the quantity of  $H_2O_2$ , the stronger catalase preparations showed a slight increase in liberation of oxygen, less strong preparations being unaffected, while weak preparations showed a retardation.

The problem often arose as to how a catalase preparation might be kept with its activity unimpaired. Held at room temperature, it decreased in activity up to a point when it started to increase, after about 50 hours. This secondary activity was shown to be due to bacteria. He tried the use of 1% toluene, which checked bacterial growth, but also affected the rate of the catalase reaction. The problem was finally solved by employing low temperature storage, and he found that placing the bottles on ice immediately after trituration and dilution appeared to be the best method of keeping over preparations of celery and spinach, but that tomato catalase lost its activity slightly during 24 hours, even when on ice. One other factor was found to have an influence on this point. The exposure of the preparation to air after cold storage removed some inhibiting factor and thereafter the catalase reaction was found to have been accelerated. The weaker the catalase reaction the greater was this effect, which reached its maximum after 6 to 8 minutes exposure to air. This effect was thought to be due to the greater solubility of  $CO_2$  at the low temperature.

Crocker and Harrington (4) describe two types of dormancy in seeds. In the one there are certain fundamental changes necessary before growth can start, which are favoured by low temperature ( $5^\circ C.$ ) and abundance of oxygen and moisture. The other is of the hard seed-coat type. They also describe a secondary dormancy imposed by the structures enclosing the embryo, as for example, in Johnson grass (*Sorghum Halapense* (L.) Pers.) which fails to germinate when kept moist at constant temperature, but which requires dry storage for after-ripening.

In making their catalase determinations they used a given weight of the finely ground seeds sifted through bolting cloth. The strength of the  $H_2O_2$  was determined by using an excess of catalase material which they found acted as a buffer to counteract the adverse effect of the acidity of the peroxide, and released the  $O_2$  quantitatively. They used 1.5 gm. of material in the case of crimson clover seed in 5 cc. of  $H_2O$  and 2 cc.  $H_2O_2$  diluted to 5 cc. They point out the necessity for neutralizing the acidity of the peroxide, discussing the effect of varying degrees of acidity on the catalase activity of Johnson grass, and conclude that an excess of  $CaCO_3$  is as effective as exact neutralization to phenolphthalein with NaOH. This point is further elaborated with other seeds. In considering the effect of the degree of pulverization they found that excessive agitation caused a partial destruction of the catalase and that the degeneration of the enzyme was relatively quick after grinding if stored in a dessicator over CaO.

Comparing the catalase activity of different parts of the caryopses of grasses, they found that the embryo showed much higher activity than the endosperm.

Among the numerous conclusions and points of interest mentioned, the following bear directly on the scope of this paper.

Catalase activity paralleled respiratory activity in seeds much more closely than viability or vigour. For equal weight immature grains showed much higher activity than mature, this preponderance being maintained even after drying and storage, but the same number of immature and mature seeds of Johnson grass (separated by means of the blower) showed approximately equal catalase activity.

The drying of seeds was shown to lower catalase activity, which was also observed to become less as seeds aged. This, however, was concluded to be not true of all seeds, as it was not observed in the case of *Amaranthus retroflexus*. They failed to find that catalase activity was directly correlated with vitality. Two graphs were prepared, one showing two curves illustrating the relation between germination and the number of hours heated at 81°C, and catalase activity and number of hours heated at 81°C. respectively. Comparison of these two graphs in the opinion of the authors, "strengthens the coagulation conception of age degeneration".

Seeds that after-ripen with dry storage but without self-imposed dormant embryos either appeared to show no change in catalase activity (e.g. *Amaranthus* spp.) or a lowering thereof (as in the case of grasses) with after-ripening; while those that after-ripen in the germinator at low temperature, having self-imposed dormant embryos, seemed to show increased catalase activity with after-ripening.

Seeds which had been treated with heat to lower their vitality showed a greater fall of catalase activity than of germination in the shorter periods of treatment, but the reverse in the longer periods in the case of Johnson grass. In air-dried seeds of *Amaranthus* spp., the catalase appeared to be comparatively heat- and time-stable the substances connected with viability, comparatively heat- and time-labile, while with Johnson grass the reverse was the case. This latter showed a loss in catalase activity under storage in a germinator at 20°C., but the loss was less marked at 7°C. The longevity of dormant seeds appeared to be limited by the exhaustion of stored foods by respiration, the intensity of which is much reduced during dormancy along with catalase activity. With the germination of the seed, the catalase activity increased. The proportion of the soluble  $\beta$ -catalase varied with different species, being responsible for about 50% of the total activity in *Amaranthus retroflexus*, and about 14 to 30% (depending on the filter used) in Johnson grass.

Repeating the experiments of Nemec and Duchon, with different varieties of pea, De Vilmorin and Cazaubon (26) found a distinct correlation between the diminution of their catalase activity and of their germination on account of age. In the case of the seeds of certain trees however, notably pine and larch, in which they felt this reaction would be of particular value because of the slow germination of these seeds, they found that there was still considerable catalase activity even in dead seeds, while it was much reduced when the seeds were heated at 100°C. for one-half hour. Hence they concluded that the method was inapplicable to these species.

Shull and Davis (25) using seeds of *Xanthium* found that catalase activity was not strictly proportional to the amount of material used. With this species, they found no variation in activity as a result of dry storage, but that germinator storage at a temperature too low for germination increased respiratory and catalase activity. Seeds collected from the field at weekly intervals showed a progressive decline in catalase activity till about the middle of April, when it began to increase as the natural germinating season approached.

Ota (23) concluded that respiratory and catalase activities run parallel throughout the dormancy period, in seeds of *Xanthium*.

Davis (6) failed to find a close correlation between catalase activity and germination as reported by Nemec and Duchon. Since, however, the loss of catalase activity seemed to lag behind the loss of viability, it occurred to him that its disorganization might be brought about in some manner that would not affect the catalase of viable seeds. He found that soaking in warm water effected this. Using the ratio:—cc.  $O_2$  liberated by soaked: unsoaked, he found that this ratio was more or less equal to unity when the germination was high, but less when the viability was low.

Instead of a given weight of material, this author used a given number of seeds. He found that in choosing between a short soak at relatively high temperature and a longer soak at a lower temperature, the former was preferable since disorganization of the catalase was more complete and there was less chance of its increase with increase of respiratory activity. The catalase content of viable lettuce seed was not reduced by soaking for one hour at  $54^{\circ}C.$ , (high temperature, short soak). Some seeds responded much more completely to the high temperature soak than to the low. He used as his basis of measurement the volume of  $O_2$  liberated after ten minutes.

With seeds showing high catalase activity he recommended grinding a large number with repeated additions of 20 cc. or more of water, and working the mass through a 60-mesh sieve till 250 cc. had been obtained. After thorough agitation a 5 cc. aliquot, to which 5 cc. of water were added, was taken for each run.

He found that the seed axis and especially the hypocotyl portion of the embryo appeared to be the first to succumb to devitalizing factors. In cases where this was true and the cotyledons or endosperm formed the bulk of the seed, the difference in catalase content of the dry and soaked seeds might not be sufficient to indicate the true condition of the viability of the seed. In such cases it was recommended that the catalase be determined on the epicotyl and hypocotyl without storage parts.

Where the seed was badly infested with fungi the test was found to be of no value, as the living fungi bear part of the catalase and protect it against decomposition in the high temperature soak.

The advantages claimed for the method are, that it is unnecessary to know the catalase content of the same kind of seed of high viability; the quick estimation of the viability of dormant seeds is possible; viability of quickly germinating seeds can be still more quickly estimated where special dispatch is necessary; and for checking up erratic results obtained by germination methods.

In a study of the catalase relations of rice under different germination conditions, Morinaga (19) found that there was only about one tenth as much catalase in dry seeds of rice as in those of wheat, oats, barley and rye. Rice germinating anaerobically showed no increase in catalase, but a gradual increase was observed in the course of germination in a medium with a reduced supply of oxygen, while under aerobic conditions of germination the catalase activity was high, being about seven-tenths as much as that in the germinating grains of wheat, barley and oats. Hence it was concluded that the ratio of increase of catalase activity is a function of the free oxygen in the medium.

The free oxygen was found to affect the development of the radicle and plumule and also of the chlorophyll of the latter. The catalase, once having been increased under aerobic germination conditions, decreased when the plant was returned to anaerobic conditions, though the growth continued. He found further that where the catalase had been increased by germination under aerobic conditions much more oxygen was used by the seedlings than in the reverse case, but the carbon dioxide relations were unchanged.

In a general discussion as to the value of catalase as an indicator of seed viability, Gračanin (9) points out that contradictory results have been obtained by different authors. He found with certain seeds a diminution of catalase activity with loss of vitality when such loss of vitality is occasioned by age. In plant tissue which has lost its vitality however, he distinguishes, after Grafe, between "dead" and "disorganized" tissue. In the former case while vitality is gone, the enzymes still retain their properties to a certain extent, while in the latter the enzymes are lost also. In order to bring about these two conditions in seeds, he soaked them in various solutions. Thus 0.05 M NaCl and 0.001 M  $\text{ZnSO}_4$  killed the cells (leaf tissue of *Mnium undulatum*) without disorganizing the catalase; 0.001 M  $\text{CuSO}_4$  killed the cell and reduced catalase activity; while 0.001 M  $\text{FeCl}_3$  and 0.001 M I destroyed both life and catalase activity. Similar results were obtained with seeds of four species.

He concludes that while loss of catalase activity indicates loss of vitality in seeds, the converse does not hold necessarily, and points out how erroneous conclusions could be reached by judging the vitality of seed by the catalase test, if such seed had been shipped by ocean and become injured by the salt water.

The two following papers have been left for discussion at this point on account of certain mathematical features they present, which it was felt made it advisable to discuss them together, though the discussion of the more general features will be considered at the same time.

Morgulis and Beber (17) observe that in a previous paper by the senior author (16) the optimum temperature for catalase activity was found to be between  $0^\circ\text{C}$ . and  $10^\circ\text{C}$ . It is to be noted that in the work of these authors, the criterion as to catalase activity is not the rate of liberation of oxygen as with most of those previously quoted, but the total amount of oxygen that a given quantity of the preparation is capable of liberating. Hence, although the reaction proceeds much more slowly at the low temperatures mentioned, it does so much more completely, the difference being due to the partial destruction of the catalase at the higher temperatures.

The material used for the experiments dealt with in this paper was a semi-pure beef kidney preparation which, having been maintained at pH 7.0 by the use of the Kolthoff phosphate-borax buffer, had retained its full strength for three years. The experimental temperatures ranged from 0°C. to 30°C. The method of temperature control was an improvement over that previously used and was very accurate. As the experimental temperature was increased it was found necessary to increase the catalase concentration to make up for the destruction of the catalase during the experiment.

Figure 2, copied from the paper under discussion, shows the relation between catalase activity and temperature with varying amounts of the catalase preparation.

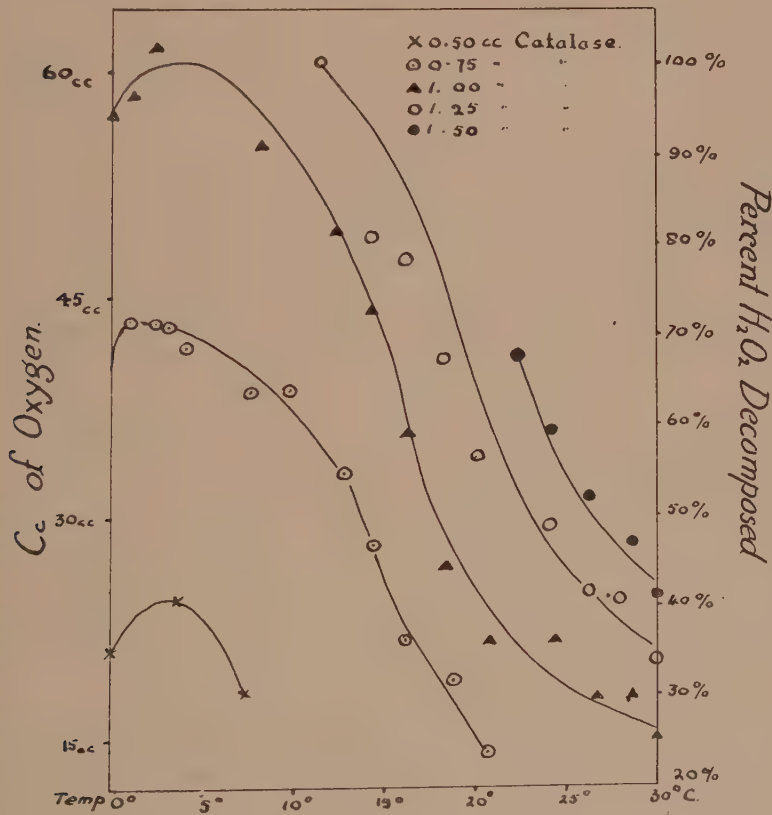


Figure 2.

The optimum temperature is found to lie between 1°C. and 3°C. The variation between these temperatures is so slight that the authors considered that the mean, 2°C. might be set as the optimum temperature.

In Figure 3, also copied from their paper, the results of the same series of experiments are arranged in such a way that the percentages of H<sub>2</sub>O<sub>2</sub> decomposed are plotted against the relative catalase concentrations. The straight line graphs so produced are therefore catalase isotherms.

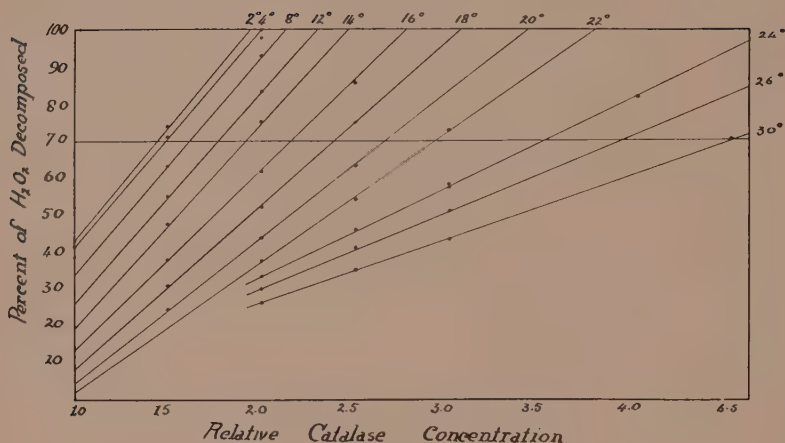


Figure 3.

In the paper previously quoted (16) Morgulis found that the course of the catalase reaction at the point where 70% of the  $\text{H}_2\text{O}_2$  was decomposed, followed exactly that of a bi-molecular isotherm, and had previously been proposed as a means of standardizing catalase preparations. By drawing the horizontal line corresponding to this degree of peroxide decomposition, the abscissa shows the relative catalase concentration which will manifest this activity at varying experimental temperatures.

Assuming that all of the catalase is active at the optimum temperature ( $2^\circ\text{C}.$ ) it is possible to calculate how much is destroyed at a higher temperature; for, regarding the amount of catalase which at  $2^\circ\text{C}.$  effects 70% decomposition as one enzyme unit, the relative amount which is still active at any other temperature may be obtained. If the values of the relative catalase activity thus calculated are plotted against their corresponding temperatures, the curve, Figure 4 (also copied), is obtained, which corresponds to the equation:—  $y = 0.58 + 0.425 \sin 90/19 (10 - t)$ , when  $y$  equals the relative catalase activity and  $t$  the experimental temperature.

This expression holds good up to a temperature of  $24^\circ\text{C}.$ , but beyond this point there is a divergence. While this divergence is of no practical value, since higher temperatures than this are never employed in catalase determinations, there is a theoretical interest in this deviation. In a previous paper (Morgulis, Beber and Rabkin, 18) it was shown that catalase destruction is a mono-molecular reaction with a temperature coefficient which increases moderately for higher temperature ranges; the temperature coefficient for the catalase reaction however having no fixed value, but increasing greatly as the experimental temperature rises. It follows from the new observations that  $24^\circ\text{C}.$  is a critical temperature for the catalase reaction, the rate of the catalytic reaction being so much greater than that of the enzyme destruction reaction that the volume of oxygen set free becomes progressively greater than the theoretical amount for temperatures above  $24^\circ\text{C}.$

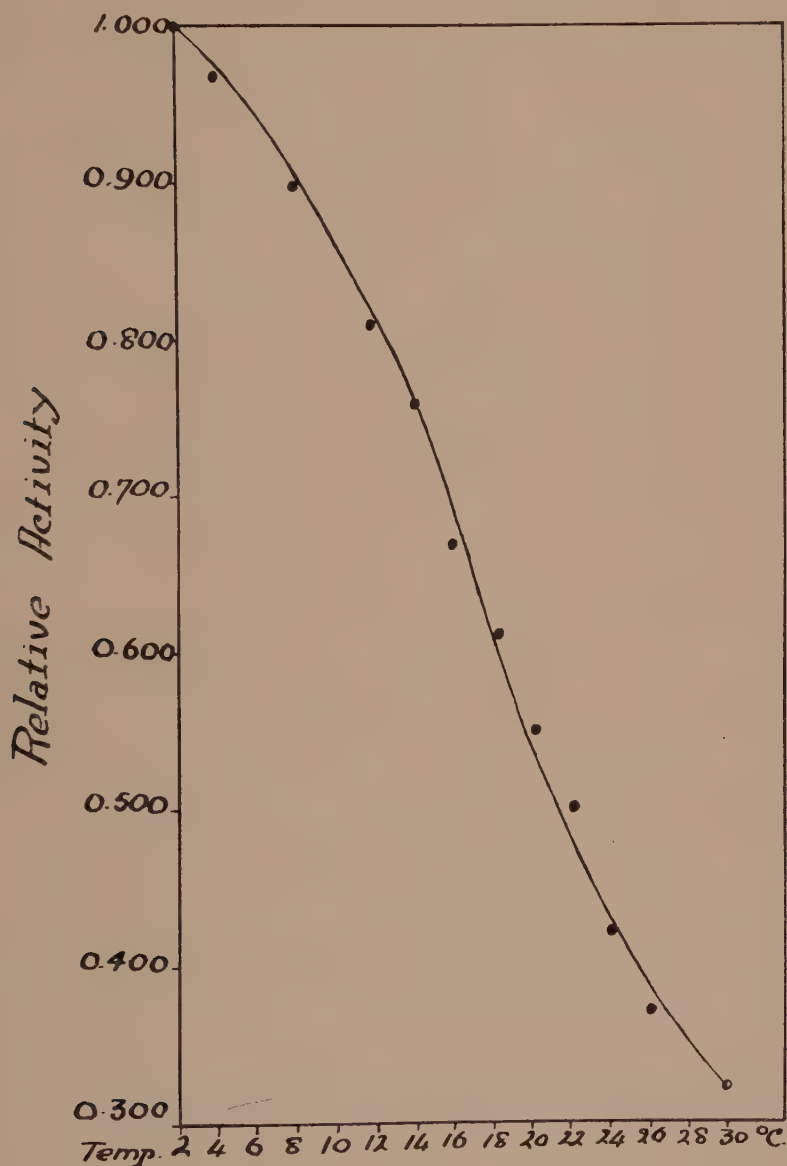


Figure 4.

This curve make it possible now to find the actual number of enzyme units no matter at what temperature the experiment is performed. Experimenting at temperatures as low as 2°C. is not practicable and even if it were it would not be desirable, for the reaction at this temperature is very slow, whereas at 16 to 20°C. the reaction is complete after from 30 to 90 minutes. The results obtained at any of these temperatures may easily be corrected for the catalase destroyed at the temperature used. It is necessary to determine the per cent  $\text{H}_2\text{O}_2$  destroyed by at least two different catalase con-

centrations (which should produce between 50 and 80 % decomposition but in any case not more than 90%), whereby the catalase isotherm may be established and the catalase concentration producing 70% decomposition determined. The relative activity at the experimental temperature may be read from curve Figure 4. The quantity of catalase producing 70% decomposition ( $Q$ ) divided by the factor for relative activity ( $A$ ) at the temperature of the experiment gives the actual amount of the catalase used in the test; or if  $Q/A$  at  $2^{\circ}\text{C}$ ., where  $A = 1$ , is considered as the enzyme unit, the figure obtained is the number of enzyme units.

They concluded that any catalase preparation could thus be standardized on a strictly quantitative basis, which is easily and exactly reproducible and, in experiments designed to prove this point, found their conclusions justified.

In a paper dealing with the relationship between catalase activity and respiration of germinating seeds Rhine (24), after discussing the properties and probable functions of catalase and various theories concerning the same, pointed out that the fact that in many cases a parallelism had been found between catalase activity and respiration has led the former to be determined as a measure of the oxidation rate; but that there were discrepancies which it was the intention of her paper to solve.

The reaction vessel was operated in a water-bath maintained at  $21$  to  $22^{\circ}\text{C}$ ., and all results were calculated to standard temperature and pressure. In all experiments 5 cc. of Oakland dioxygen neutralized with  $\text{N}/10$   $\text{NaOH}$  was the quantity used. The tissue was ground with  $\text{CaCO}_3$  and sand and used quantitatively with 15 cc.  $\text{H}_2\text{O}$ . When the temperature of the bath was reached the peroxide was added, and shaking commenced 15 seconds thereafter. One 10-minute reading was taken, excess pressure being avoided by adjusting the level in the burette. The degree of pulverization, which was done dry, was determined according to the operator's "best judgment", being as nearly as possible equivalent to grinding dry wheat for four minutes.

There follows a discussion of the objection of Morgulis *et al*, "that a time reading, arbitrarily chosen for the measurement of the catalase-hydrogen peroxide reaction, cannot afford an accurate measurement of catalase activity. Under the law of mass action, an arbitrary time limit would not express the results of comparable stages in the reaction when the amount of one or more substances was varied. Thus when the proportion of catalase to  $\text{H}_2\text{O}_2$  is high, a 10-minute reading would express the results of a much greater part of the entire reaction than it would when the amount of catalase is relatively small". The authoress shows a table in which this is illustrated. She goes on to point out that Morgulis stated that a great excess of either of the reacting substances exerts a depressive influence on the reaction, as a result of which he argued that catalase determinations could only be compared by comparing the amounts of catalase preparation required to liberate equal volumes of oxygen. The impracticability of this is pointed out and a remedy suggested. A series of catalase determinations was made involving a wide variation in the amount of the catalase preparation used (in this case wheat), showing sufficient excess of catalase at one end and of  $\text{H}_2\text{O}_2$  at the other for this depression to be produced. Having calculated the volume of oxygen lib-

erated per gram of material, the highest value was taken as unity and the necessary correction factors calculated as shown in the following table (quoted from Rhine) :—

TABLE 1.

Weight in grams	Cc. O <sub>2</sub> liberated in 10 minutes	Cc. O <sub>2</sub> per gram	Factor
0.02	0.49	24.55	1.34
0.04	1.01	25.55	1.30
0.06	1.56	26.00	1.26
0.08	2.06	25.76	1.28
0.1	3.01	30.10	1.07
0.2	6.38	31.94	1.03
0.4	12.92	32.30	1.02
0.6	19.77	32.95	1.00
0.8	24.55	30.69	1.06
1.0	30.80	30.80	1.07
1.2	35.82	29.84	1.13
1.4	39.49	28.20	1.14
1.6	42.02	26.26	1.25
1.8	44.49	24.71	1.33
2.0	47.82	23.91	1.37

All her further results were corrected with these factors. Another table is given showing similar data but using different volumes of a water extract of rye ovules. These two tables gave curves varying in type, but since in subsequent experiments the ground seed type of material was used, the former set of factors was employed. All tests were run in triplicate.

She found that, while there was a large and immediate rise in respiratory activity when seeds were put under germinating conditions, the catalase activity decreased in the early stages of germination in the case of six kinds of seeds tested; the initial decrease however was followed by the rise generally reported. Thus the early curve of respiration was found to diverge widely from that of catalase activity.

Catalase was found to decrease slowly, almost to exhaustion by prolonged soaking of seeds in oxygen-free water.

The decrease in germinating wheat was evident both in the embryo and endosperm; the subsequent rise however, while not confined to the embryo, was much more marked therein.

In ripening seeds the catalase was found to decrease both per unit of wet and of dry weight. It increased per ovule as the seed grew, but after ripening began decreased rapidly with lowering of water content.

The production of catalase was found to be indirectly connected with oxidation, and Loew's suggestion was advanced, that the function of catalase is to remove either hydrogen peroxide or some other substance as yet unknown which the catalase has the power to decompose, and which is formed in the tissues as the result of metabolic processes.

In her opinion catalase activity could only be used as an indicator of metabolism in those cases where there was no rapid change in respiration.

## SUMMARY

A number of biochemical methods of estimating the viability of seeds have been considered. The method involving the determination of catalase activity has been chosen for further study as giving promise of the solution of the problem and also as holding the possibility of throwing light on some of the problems of dormancy and delayed germination.

Literature on the catalase reaction has been reviewed. Among authors who have attempted to use the catalase reaction as a measure of seed viability considerable difference of opinion exists as to its usefulness. Two methods which are claimed by their authors as giving a measure of seed viability have been described. In the one, the difference between the catalase activity shown by the untreated crushed seed and that shown by the crushed seed after treatment on the water-bath at 100°C. for 20 minutes is taken as the measure; in the other the ratio:—catalase activity of seed soaked at fairly high temperature: that of seed not soaked is the measure.

The optimum pH for the catalase reaction has been shown to be 7.0. The method of neutralization of the acidity of the peroxide with excess of  $\text{CaCO}_3$  and grinding the material with excess of this substance has been used by a number of investigators to produce conditions approaching this optimum and appears to be a satisfactory means to accomplish this end.

A depressive effect due to excess of either the peroxide or the catalase material has been found by several authors.

A number of methods have been proposed as a basis for expression of catalase activity. The most practical for the purpose of this work appears to be the volume of oxygen liberated after a given time corrected by a factor to allow for this depressive effect. This is more fully discussed in the next section.

The importance of comparing the activities of catalase preparations under uniform temperature conditions has been stressed. The most suitable temperature from a practical point of view is 20°C., though this is not the optimum temperature for the catalase reaction.

Catalase has been reported to exist in a soluble and an insoluble form; while one author considers these two forms to be different degrees of peptization of the same substance.

Respecting the quantity of catalase material to use, some workers have used a given weight, others a given number, of seeds. The latter is satisfactory where the seed is uniform, but the former is perhaps the more generally useful. It is to be noted, however, in comparing seeds of different degrees of maturity directly, that Crocker and Harrington (4) found that a given number of immature seeds exhibited the same activity as the same number of mature seeds of the same species, though they weighed less.

During the course of the catalase reaction the reagents should be agitated to prevent the accumulation in solution of the oxygen liberated; both in order to ensure that the total volume of oxygen liberated shall be measured and also to allow the reaction to proceed towards completion undisturbed by the presence of one of the products of the reaction. The speed of shaking appears to

influence the course of the reaction particularly in the earlier stages. From this point of view therefore it is better so to adjust the proportions of the reagents that the reaction may have proceeded well on its way by the end of the time limit set.

In the preliminary experiments discussed in the next section the author confirmed a number of the observations summarized above.

## EXPERIMENTAL PART

### DEVELOPMENT OF A METHOD FOR SEED CATALASE DETERMINATIONS

While some of the methods for the determination of seed viability outlined, which did not make use of the catalase reaction, appear to be promising, it was felt that the catalase method not only gave promise of the solution of the problem, but that it might, moreover, throw more light on seed germination problems.

### MATERIALS

It was thought best to confine the following study to one kind of seed in order to avoid undue complications and that the study might be more complete; accordingly spring wheat has been used throughout.

Merck 3%  $\text{H}_2\text{O}_2$ , which in repeated tests was shown to be very fairly uniform in strength and which could be secured locally, was used.

Merck precipitated  $\text{CaCO}_3$ .

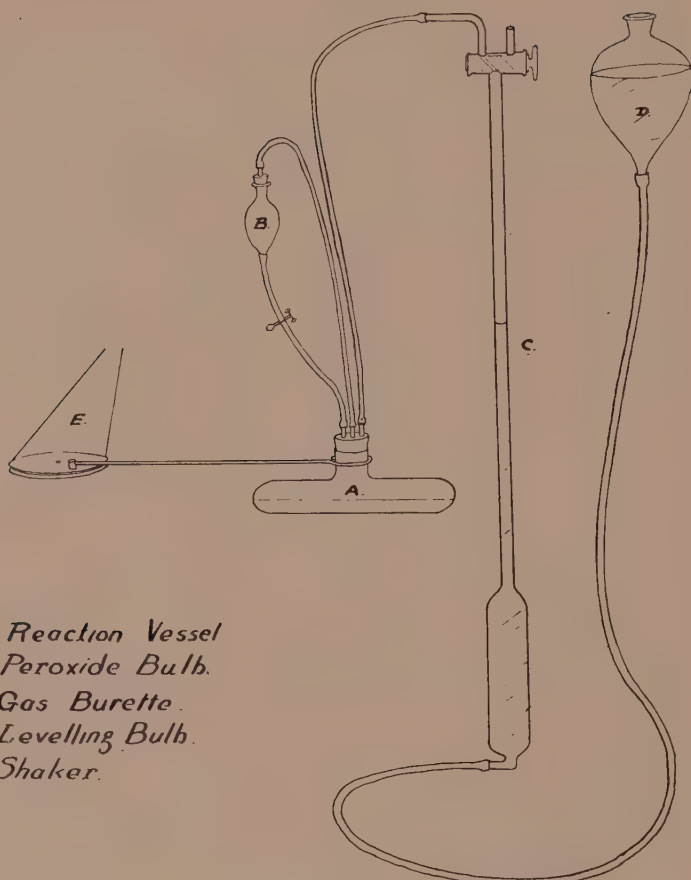
### APPARATUS

The apparatus used was similar to that shown in Figure 5, the reaction vessel being operated by an electric shaking mechanism, the speed of which could be varied within wide limits.

In the early part of the work an attempt was made to keep the temperature of the laboratory (about 12' by 14') constant at 20°C. by a thermo-regulated auxiliary heater. This not proving very satisfactory, the reaction vessel was immersed in a constant temperature water-bath, which was operated by a relay mechanism. This in turn not proving as satisfactory as could be desired, the author constructed a constant temperature cabinet, a cut of which is shown in Figure 6, in which the entire apparatus was placed, the same relay mechanism, also homemade, being employed. This effects a temperature control within  $\frac{1}{4}^\circ\text{C}$ . and was set to operate a fraction under 20°C. A suitable worm gear clutch mechanism enables the operator to set the shaker in operation from the outside of the cabinet.

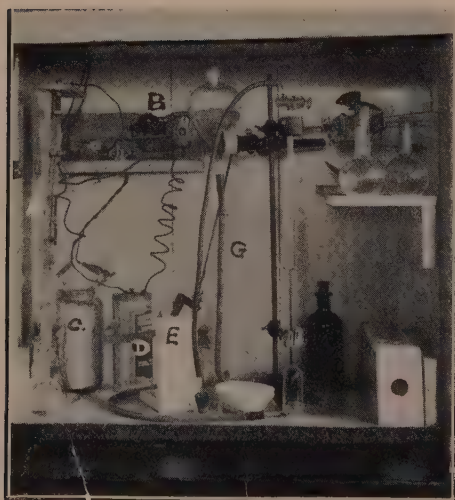
While at first a reaction vessel shaped like that in Figure 5 was used, this was later replaced by a Y-shaped vessel which was much more convenient.

During the course of the reaction the leveling bulb was left on its stand, but a graph was prepared from which could be read the actual volume of  $\text{O}_2$  displaced corresponding to the volume read on the burette. This correction of course was always made; also, in the latter part of the work all volumes were corrected for barometric pressure.



- A. Reaction Vessel*  
*B. Peroxide Bulb.*  
*C. Gas Burette.*  
*D. Levelling Bulb.*  
*E. Shaker.*

Figure 5. Apparatus used for catalase determinations.



- A. Thermostat.*  
*B. Relay.*  
*C. Condenser.*  
*D. Battery operating relay.*  
*E. Rocker.*  
*F. Fan and Gear Box.*  
*G. Burette assembly.*

Figure 6. Constant temperature cabinet.

## EXPERIMENTAL

In regard to the basis for expression of catalase activity, five methods have been reviewed. These are:—

- (1) The volume of oxygen liberated after a given time.
- (2) The time required to liberate a given volume of oxygen.
- (3) A reaction constant derived by the use of a modification of the mono-molecular formula.
- (4) The total amount of oxygen a given quantity of catalase is capable of liberating or, alternatively, the amount of catalase preparation capable of liberating a given volume of oxygen.
- (5) A modification of (1) above.

While the first of these affords a very convenient measure it has the objection that comparisons are not made between comparable stages of the reaction. Thus strict proportionality between the amount of catalase present and its measurement on this basis cannot be expected. This is illustrated by the curves shown in Figure 7, in which the author has compared the activity of equal weights and equal numbers of the germ- and brush-end halves of wheat kernels. After 600 seconds the activity of the brush-ends to that of the germ-ends is as 6.6:14, i.e., the former shows 47% of the activity of the latter; while after 300 seconds the proportion is 5.1:9.7 or 52.6%. Moreover, no regard has been paid to the depressive effect of excess of one or other of the reacting substances.

This latter point is also one affecting the second method. On the other hand, since the volume of the oxygen liberated is the same in two comparative readings, the concentration of the substrate is the same and the reactions are hence at comparable stages, yet it is a matter of some moment as to which volume to decide to use as will be made clear from the following considerations. If in Figure 7 we compare the activities of the two curves on this basis at 3 cc. and 6 cc. of oxygen liberation, we find that the times required are 132:63 seconds to liberate 3 cc. for the brush- and germ-ends respectively, and 452:152 for the same to liberate 6 cc. Since the activity is the reciprocal of the time we find that at 3 cc. the brush-ends show 47.7% of the germ-end activity, and at 6 cc. 33.6%. It would be necessary, therefore, working with catalase preparations of known strength, to determine the best volume of oxygen liberated to use for comparison. A further objection is that the possible error is much greater in the time reading than in the volume reading, as will be seen on examination of the brush-end curve Figure 7. This is the more marked when the time approaches that required for the completion of the reaction.

The third method mentioned above was the use of the formula

$$K = \frac{1}{\sqrt{t}} \log \frac{a}{a-x}$$

*Relative Catalase Activity of  
germ and brush ends of wheat*

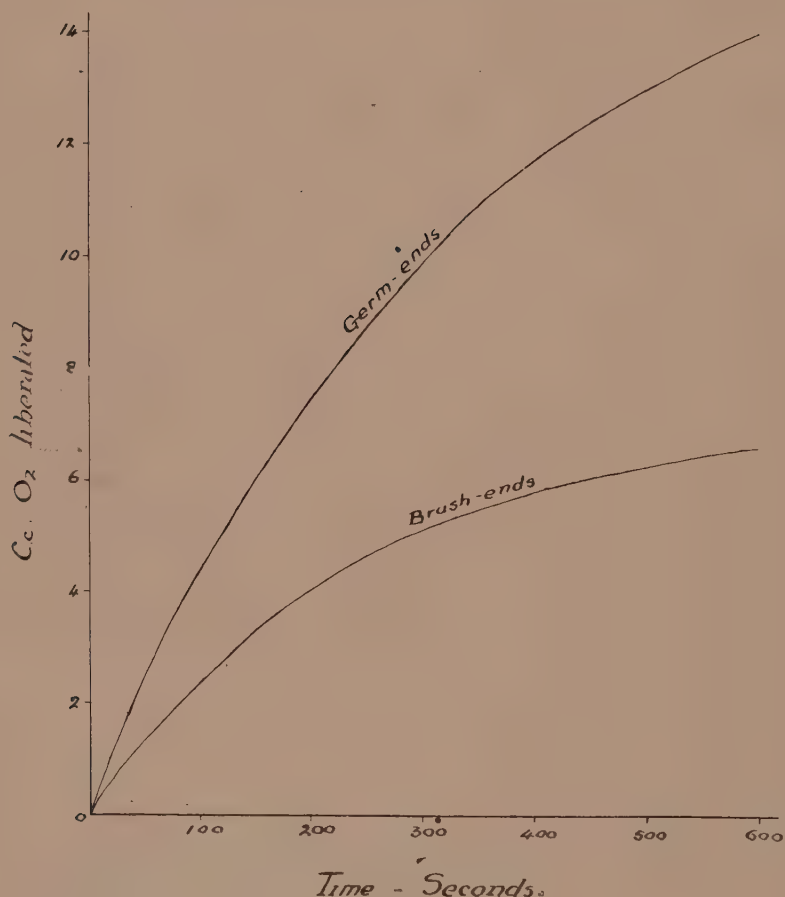


Figure 7.

Morgulis (16) showed that the mono-molecular formula

$$K = \frac{1}{t} \log \frac{a}{a-x}$$

is only applicable to the catalase reaction when the reacting substances are present in such proportion that 95 to 100% decomposition of the peroxide occurs. As the proportions are so adjusted that smaller percentages of the peroxide are decomposed the formula must be changed accordingly. With about 70% decomposition the formula for a bi-molecular reaction was shown to apply. The mono-molecular formula did not fit the results obtained by Nemec and Duchon, who therefore devised the modification above, in which they substituted  $\sqrt{t}$  for  $t$ . Even this modification, however, did not fit the curves obtained by the present writer. In an investigation into this point it was

found if  $K$  were kept constant the experimental  $t$  was greater than the theoretical  $t$  by a number which increased by the power of  $x$ , such that, if this number were called  $u$  formula became

$$K = \frac{1}{t-u^x} \log \frac{a}{a-x}$$

This value  $u$  is dependent on the curve itself and may be deduced by means of a quadratic equation obtained from two values of  $x$ , the one double the other. (Since  $K$  is constant

$$\frac{1}{t-u^x} \log \frac{a}{a-x} = \frac{1}{t-u^{2x}} \log \frac{a}{a-2x}.$$

This formula fitted some of the curves very satisfactorily, but not others. This appeared to be due to the fact that variations in the speed of shaking affected the shape of the curve such that with two experiments identical except for the rate of shaking, two entirely different values of  $K$  were obtained, the sharper curve giving the higher value. Since, however, the reactions were never allowed to go to completion (as, keeping the practical end in view, this would require too long a time) it was impossible to tell to which category the reaction was related, i.e., whether to apply the bi-molecular or other formula.

The fourth and fifth methods have already been fully discussed in the review of literature. The fifth, the calculation of a set of factors to correct readings in which the depressive effect of one or other of the reacting substances is in evidence, as suggested by Rhine, appears to afford a satisfactory solution to all these difficulties, is convenient to apply and enables one to use the simplest and least troublesome reading, namely the volume of oxygen liberated after a given time.

The adverse effect of acidity on the catalase reaction has been stressed. The use of an excess of  $\text{CaCO}_3$  both in the ground material and in the peroxide is a convenient means to assure practically the optimum pH; but since the peroxide decomposes spontaneously rather rapidly it is inadvisable to neutralize the acidity of the peroxide till just before the experiment.

Since it has been concluded that an arbitrary time limit reading corrected by a suitable set of factors affords the most practical measure of catalase activity, it is necessary to work with a carefully standardized peroxide solution.

Among a series of preliminary experiments carried out by the author, are some which throw some light on these points. In these the stated quantity of seeds was ground with a pinch of  $\text{CaCO}_3$  and sand and with sufficient water to form a paste. Grinding was continued till a smooth paste had been secured, when sufficient water was added in successive portions to make up a total of 100 cc. water added. This was allowed to extract the catalase for a given length of time. Four portions, each sufficient to provide an aliquot of 10 cc., were then withdrawn and centrifuged for varying lengths of time, the first to be tested for 15 minutes and each subsequent one an additional 15 minutes. It was found that 15 minutes centrifuging at 1000

revolutions per minute was often sufficient to bring the aliquot to a stable condition of activity, but that 30 minutes centrifuging would always bring this about. This is illustrated in table 2.

TABLE 2. *Cc. O<sub>2</sub> liberated after unit time by samples centrifuged for different periods.*

Series	Expt.	Centrifuged Minutes			
		15	30	45	60
22	1a	5.2	5.3	5.3	5.4
22	1b	8.2	6.2	6.3	6.3
22	2a	2.7	2.8	3.0	2.7
22	2b	4.4	4.2	4.2	—
22	3a	4.4	4.3	4.1	4.2
22	3b	6.4	5.9	5.8	5.8
24	1	7.8	7.1	7.0	6.8
24	4	7.3	6.8	6.7	6.8

Using 10 cc. of a peroxide solution having 134.4 cc. available O<sub>2</sub>, the results shown in table 3 were obtained. In this series a given number of seeds of different 100-kernel weights were used, the procedure outlined above being followed.

TABLE 3. *(Series 24). 50 kernels of wheat of different weights compared.*

Sample No.	Weight	Cc. O <sub>2</sub> after 475 seconds	Cc. O <sub>2</sub> per unit weight
4	1.90	7.18	3.78
1	2.04	7.38	3.62
3	2.19	8.66	3.95
5	2.19	9.24	4.22
2	2.37	10.76	4.54
6	2.41	11.68	4.85

At the time this series was carried out certain points which have come to light in the preparation of the foregoing review were not fully appreciated, hence samples Nos. 1, 2 and 3, which were done at a different time to Nos. 4, 5 and 6, cannot be directly compared with them. Nevertheless, the general depressive effect of excess of peroxide is clearly shown. All the samples were from the same bulk sample and were selected according to size. Each result is the average of the closest two or three of at least three runs.

In another series (Series 23) different numbers of seeds of the same kernel-weight were used. The peroxide strength was approximately 100 cc. available O<sub>2</sub> in 10cc. of solution. Table 4 shows the results of this series.

TABLE 4. *(Series 23) Varied numbers of kernels of the same kernel weight compared. I.*

Sample No.	No. of seeds	Weight	Cc. O <sub>2</sub> after 275 seconds	Cc. O <sub>2</sub> per unit Number or weight
1	50	2.19	7.55	1.51
2	60	2.63	10.71	1.79
3	70	3.07	11.88	1.70
4	80	3.50	15.13	1.89
5	90	3.94	16.56	1.84

Series 25 was similar to the above, except that different numbers of kernels were used and a reaction chamber of different shape was employed; also the peroxide was standardized to exactly 100 cc. available  $O_2$  in 10 cc.

Table 5 gives the results of this series.

TABLE 5. (*Series 25*). *Varied numbers of kernels of the same kernel weight compared. II.*

Sample No.	No. of seeds	Weight	Cc. $O_2$ after 275 seconds	Cc. $O_2$ per unit Number or weight
1	30	1.28	3.52	1.17
2	40	1.71	5.70	1.43
3	50	2.14	9.13	1.83
4	60	2.57	10.95	1.82
5	70	3.00	13.16	1.88

These two series also show the depressive effect of a preponderance of peroxide. In Series 25 there is seen to be a sudden jump in activity between samples 2 and 3. Comparison of samples 3, 4 and 5 of this Series with samples 1, 2 and 3 of Series 23 also shows a relatively increased activity for the three samples of Series 25 under consideration. These samples were given much more vigorous shaking, namely four excursions per second as against one-half per second for the remainder of the samples of these two series. We must conclude therefore that speed of shaking does influence the speed of the catalase reaction when such widely divergent speeds are compared. That this effect is greater during the earlier stages of the reaction is shown in table 6 in which the activities of two samples are compared after 150 seconds and 600 seconds for different shaking speeds.

TABLE 6. *Shaking speeds compared.*

Sample No.	Shaking speed	Oxygen liberated		Relative activity	
		150 seconds	600 seconds	150 seconds	600 seconds
25/1	$\frac{1}{2}$	2.1	5.5	64	95
25/1a	4	3.3	5.8	100	100
25/2	$\frac{1}{2}$	3.9	7.8	85	95
25/2a	4	4.6	8.2	100	100

In order to get rid of undue depressive effect on account of excess of peroxide, therefore, and also to bring a greater proportion of the later stages of the reaction within the time limit set to minimize the effect of variations in shaking speed, the preponderance of peroxide used should be considerably lessened. In the rest of the experiments here reported, therefore, 5 cc. of  $H_2O_2$ , standardized to exactly 10-volume strength, have been used. In testing the peroxide, 5 cc. were diluted to 50 cc., 5 cc. of which were then tested with an excess of catalase material.

Heinicke (10) found that on letting an apple-leaf catalase preparation stand its activity increased up to one hour, by which time it had reached a stable condition. In the author's preliminary experiments, the time that elapsed from the first moment of contact between the finely crushed seeds and the water till centrifuging was commenced was  $18\frac{1}{2}$  minutes. In order

to determine whether in this matter a seed catalase preparation would behave in the same way as the apple-leaf preparation used by Heinicke, three series, N1, N1a and N2 were carried out.

In each series 2 grams of seed were ground to a paste for 5 minutes, washed into a flask calibrated to 115 cc. and shaken at intervals. In N1 and N1a sufficient preparation was poured off (after thorough shaking) into centrifuge tubes after 15, 30, 45, 60, 75 and 90 minutes to provide aliquots of 10 cc. from each tube, which were tested immediately after centrifuging; in N2 the aliquots were poured off after 75, 90, 105, 120, 135 and 150 minutes. Results are shown graphically in Figure 8.

While the three series show very different activities for their respective preparations, N1 and N1a show a sharp initial rise in activity followed by a rapid falling off, while N2 shows that this fall continues up to 150 minutes. In N2, the 135-minute result is out of line with the rest and the 90-minute test was spoilt, but the general trend is sufficiently evident.

This was further confirmed in a later series, N 11, in which aliquots were withdrawn by pipette and tested entire without centrifuging. The results of this series are shown in graph N 11 of Figure 8.

In this connection it is interesting to note, as in table 2, that the catalase activity of centrifuged samples did not diminish after standing up to 60 minutes, but diminished activity was only observed when maceration was

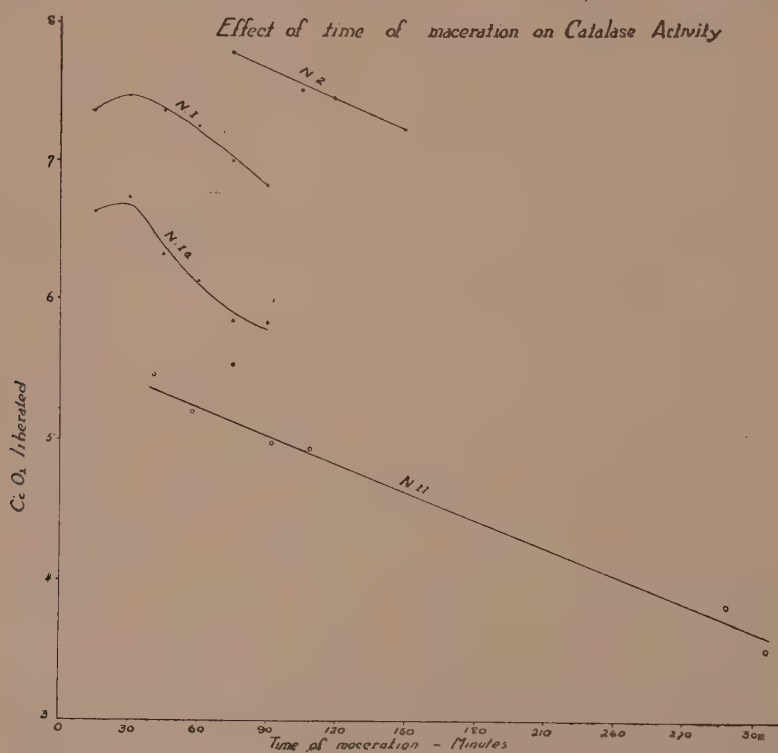


Figure 8.

continued and this, whether the samples were centrifuged before testing or tested entire. This seems rather obscure, but may indicate that the soluble ( $\beta$ ) catalase may, after solution, gradually become adsorbed by the solid particles.

It is apparent that a wheat-seed catalase preparation does not behave in this connection like the apple-leaf preparation mentioned above, but deteriorates rapidly. Further, closely comparative results seem hard to secure, since all the above samples were prepared in exactly the same manner and with the same material, except that in N1  $\text{CaCO}_3$  was omitted in the preparation of the paste, which however should tend, if anything, to decrease catalase activity instead of the reverse as was the case. Again, frothing of the preparation makes it very difficult to pipette aliquots accurately.

For these reasons it was decided to prepare samples by a dry method. To this end a number of tests were made on samples prepared in different ways. That which was finally adopted and used throughout the last section of this paper was the following:—

From 200 to 300 seeds (roughly), taken from different parts of the pile of seeds to be tested, were placed in a flat dish to facilitate inspection. From them was removed all extraneous matter, also such seeds as were too badly injured, from the point of view of the seed analyst, to be considered suitable for setting in a germination test. This sample was then coarsely ground in a coffee grinder to particles of about the size of timothy seed. After careful mixing, 1 gram was weighed and placed in a mortar with  $\frac{1}{2}$  gram  $\text{CaCO}_3$  and  $\frac{1}{2}$  gram washed sand. This mixture was then ground by hand for exactly  $2\frac{1}{4}$  minutes.

In a series of tests (N 11a) to determine the optimum time of grinding using exactly the above method, except for the point to be determined, the results shown in table 7 were obtained.

TABLE 7. *Effect of grinding catalase preparation for different lengths of time.*

Time of grinding	Cc $\text{O}_2$ liberated
2 mins.	7.65
$2\frac{1}{2}$ "	7.49
3 "	7.65
4 "	7.05
6 "	5.15
8 "	5.09
10 "	3.72

This shows a rapid falling off of activity due to excessive grinding, but little difference between two and three minutes. A fraction more than two minutes grinding was therefore adopted as just stated.

This finely ground sample was then mixed with a spatula, and from it were weighed the portions to be used for test. The test sample was transferred to one arm of the Y-shaped reaction vessel and 10 cc.  $\text{H}_2\text{O}$  added, about  $\frac{1}{2}$  cc. being added first and the vessel shaken till a fine suspension was secured, after which the balance of the water was added. This procedure was found to be important, as otherwise the powder caked, preventing the

peroxide from penetrating. In the other arm were placed 5 cc. of standardized  $H_2O_2$  and the vessel was connected to the apparatus. It was noticed, however, that a rapid absorption of air took place after attachment and before the liquids were mixed, amounting to about  $\frac{1}{2}$  cc. This was found to be complete in about 5 minutes; consequently this time was allowed to elapse before adjusting the level in the burette to zero, although the column of water in the graduated part was adjusted to reach nearly to the top during this process to avoid extra absorption due to pressure.

In order that the catalase reactions of samples showing marked differences in activity might be compared on an equitable basis, it was necessary, as has already been discussed, to prepare a set of correction factors or other means to correct for the depressive effect of one or other of the reagents. In series N 8 samples of catalase preparation varying in weight from 0.0750 gr. to 0.3750 gr. were tested in triplicate with results indicated in table 8.

TABLE 8. *Catalase units corresponding to Cc O<sub>2</sub> liberated.*

Weight of sample	Catalase units	Cc O <sub>2</sub> liberated
0.0750	2	1.49
0.1125	3	2.60
0.1500	4	3.89
0.1875	5	4.85
0.2250	6	6.11
0.2625	7	7.23
0.3000	8	8.20
0.3375	9	9.17
0.3750	10	10.43

This was plotted on the graph Figure 9 and in all subsequent work, except where specifically mentioned, the somewhat arbitrary catalase unit has been read from it and used as a measure of the catalase activity of the sample.

Samples prepared in this way were found in repeated tests to suffer no depreciation in activity for several days.

#### THE CATALASE REACTION APPLIED TO THE STUDY OF SEED VIABILITY

In the papers of Crocker and Harrington (4) and Davis (6) who failed to find the correlation between catalase activity and germination claimed by Nemec and Duchon, no mention is made as to whether the experiments of the latter were exactly duplicated. Apparently, according to the writings of these and other authors on catalase activity in relation to seed germination, (except Nemec et Duchon, and De Vilmorin et Cazaubon) the catalase activity measured is the total activity, whereas that which Nemec and Duchon found to be correlated with germination was the total activity less the residual activity exhibited when the same material had been treated for 20 minutes at 100°C. on the water-bath. Davis, however, did not base his method on the direct comparison of the total catalase activity of seeds but rather on the relation exhibited between the total activity of the seed before and after treatment of the whole seed by a soak of from one to several hours at a temperature of from 54°C. to 30°C.

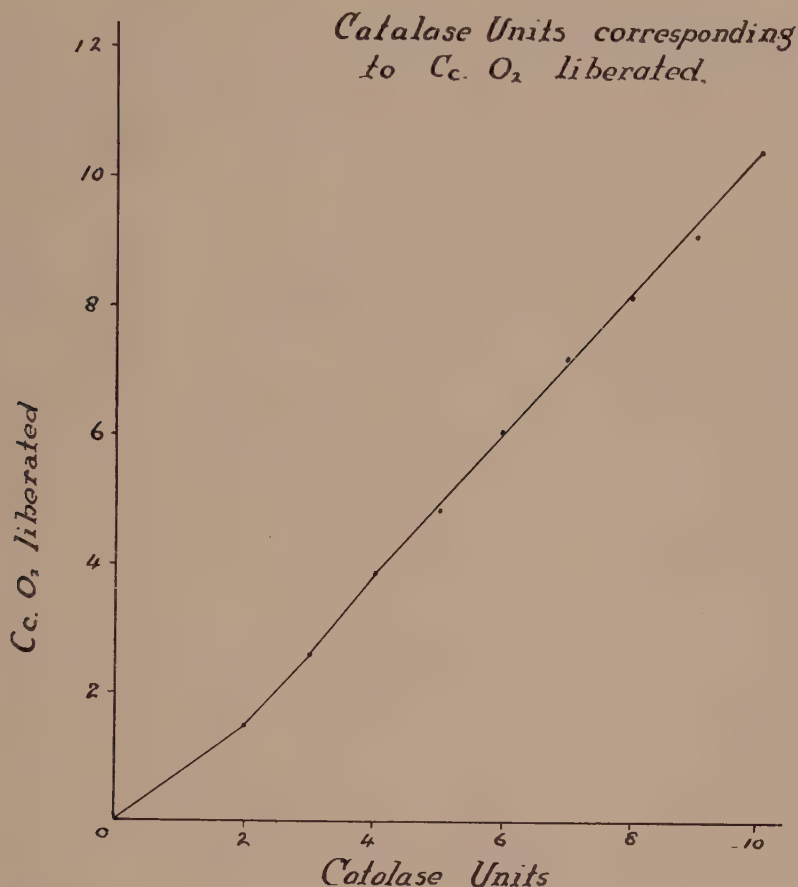


Figure 9.

It would appear at first sight that there is a connection between this treatment and that of Nemec and Duchon but the results obtained are exactly the opposite in the two cases. With his treatment Davis finds that the ratio treated: untreated approximates unity in the case of seed of high viability and is less than unity in the reverse case, while the results of Nemec and Duchon, though the authors did not express them in that form, would show approximation of the ratio to unity with seed of low viability but much less than unity in the reverse case. The explanation appears to be in the more drastic nature of the treatment in the latter case which, one would deduce from their paper, would reduce the treated seed to a condition of showing 'catalase activity not related to viability' the subtraction of which from the total catalase activity would give the 'catalase activity presumably related to viability'. In the case of Davis' treatment, however, since the seed was still whole and thus protected to a certain extent against catalase disintegration and since further, the treatment was not drastic enough to destroy the catalase except in the case of seeds of low viability, these would be the only kind to sustain loss in catalase, and that roughly to the extent of what in Nemec and

Duchon's experiments might be considered 'catalase presumably related to viability'.

Both methods are claimed by their authors to give figures indicative of the viability of the seed, though the results reported by Davis do not show very much more than that a sample has low or high viability; i.e., there appears to have been no attempt made to connect a given catalase result with a definite percentage of germination.

#### MATERIALS AND METHODS

In this section the methods outlined in the previous section were used in conjunction with the constant temperature cabinet previously described.

Samples of wheat of the 1920 and 1921 crops which had been used in frost studies and represented many different stages of maturity and frost injury, and of which the full history was known, were kindly supplied by the Department of Field Crops, University of Alberta. In addition to these there were some samples which had passed through the laboratory, presenting different degrees of weathering and other injury. Only samples which were thoroughly after-ripened by prolonged storage were used in order that difficulties of interpretation which might result from the use of dormant seed might be avoided.

#### EXPERIMENTAL

Owing to the fact that the dry method appeared to give the best results and that it had been developed to the stage at which it might be relied upon, it was felt best first to check the method outlined by Nemec and Duchon.

*Series N 9 a.* The samples used in this series with their corresponding germinations and other data are given in table 9.

TABLE 9. *Samples used in Series N 9 a.*

Sample	Germ. 12 days	Remarks	Degrees of frost to which subjected
Plot D/20	14	Mealy dough	1, 2, 4, 7, 13.
65-1997	22	Badly frosted and weathered	Exact degree unknown
D-11-21	34	Clear green	14
B-11-21	36	Yellow kernel	6.5, 14.
C-11-21	65	Green to yellow	6.5, 14.
C-12-21	71	Pale yellow	6.5, 14.
65-6501	80	Weathered, plump	Frosted, but exact degree unknown.
C-10-21	88	Green to yellow	6.5.
#1	95	1926 registered crop, very high quality but maintained at R.H. 71% several months.	0.
C-1-21	99		0.

(Notes on all samples except 65-6501, 65-1997, and #1 taken from notes made by the University of Alberta at time of harvesting.)

Catalase tests were made on these samples, both on the treated and untreated ground material, the treatment consisting of placing the weighed experimental material for 20 minutes in an oven containing a dish of water and regulated to 98°C, this being the nearest approach to Nemec and Duchon's treatment on the water-bath that it was possible to make under the circumstances. (The boiling-point of water at the elevation of Calgary is approximately 98°C.)

Three replicates were made on each of the treated and untreated samples. Where one replicate was divergent from the other two, the two close ones were used; where there was a moderate spread between the three, the average of all three; but where there was no close agreement, a fresh sample was prepared and tested. These remarks apply also to Series N 13, reported later.

Results of these determinations are given in table 10.

TABLE 10. *Series N 9 a. Catalase Determinations.*

Sample	Germ.	Cc. O <sub>2</sub> liberated		Nemec and	Cc. O <sub>2</sub> ratio
		Untreated	Treated	Duchon figure	
Plot D/20	14	6.43	3.16	5.75	.491
65-1997	22	5.77	2.73	3.04	.473
D-11-21	34	8.74	5.68	5.36	.650
B-11-21	36	6.32	3.94	2.38	.623
C-11-21	65	6.60	4.14	4.31	.627
C-12-21	71	6.24	3.44	4.90	.551
65-6501	80	6.36	4.29	2.07	.675
C-10-21	88	7.40	4.62	4.87	.624
#1	95	7.38	4.68	2.70	.634
C-1-21	99	10.15	7.18	5.19	.708

In the fifth column is the figure Nemec and Duchon use for their expression of seed viability. This figure has been obtained by subtracting the number of cc. of oxygen liberated by the treated sample from that liberated by the untreated; but note that on account of the great activity in all samples except 65-1997, B-11-21, 65-6501 and #1, in which 0.2625 grams were used, the size of the sample had to be reduced to 0.1500 grams, hence the figure obtained by subtraction had to be multiplied by 7/4. There appears to be no correlation between this figure and the germination of the seed.

Since these samples show very uneven catalase activity, it was thought that perhaps if the ratio of the activity of the treated to that of the untreated were compared, a correlation might be revealed. In the sixth column these ratios are tabulated but again no correlation is apparent.

If these samples are arranged in order of their maturity, as indicated in table 9, there is seen to be a striking inverse correlation between catalase activity and maturity. This is shown in table 11, the factor 7/4 being introduced as before to bring all samples to an even weight basis.

TABLE 11. *Maturity of seed as affecting catalase activity.*

Sample	Catalase Activity	
	Untreated	Treated
C-1-21	17.76	12.57
D-11-21	15.30	9.94
C-10-21	12.95	8.09
C-11-21	11.55	7.25
C-12-21	10.92	6.02
Plot D/20	11.28	5.53
B-11-21	6.32	3.94
65-1997	5.77	2.73
65-6501	6.36	4.29
#1	7.38	4.68

Not much difference between maturity of these samples but arranged according to best judgment.

Nemec and Duchon worked with samples of presumably the same degree of maturity, but which had lost their vitality through age. The effect of seed exhibiting increased catalase activity with immaturity may be to mask the effect of the treatment suggested by these authors.

It occurred to the present writer that possibly the treatment at  $98^{\circ}\text{C}$ . for 20 minutes did not in fact reduce the test sample to a condition of exhibiting only thermo-stable catalase activity and to question whether there was such a thermo-stable residue. In Series N 12 this point was investigated.

In the series just discussed, the figures used have been on the basis of cc.  $\text{O}_2$  liberated and not corrected to catalase units, since this is the basis used by Nemec and Duchon. The conclusions are unaltered, however, when catalase units are used as the basis. In Series N 12 and N 13 catalase units have been used throughout.

*Series N 12.* In this series the test samples, all prepared from one bulk sample, were heated for 10, 20, 30, 45, 60, 75 and 90 minutes respectively. All tests were made in quadruplicate, two replicates being from one grind and two from another for each treated sample, and from each grind a check untreated test was also made. Results were then calculated to the basis of the highest set of checks, since absolute uniformity between the different grinds was not obtained. The graph, Figure 10, shows the results obtained in this series.

*Series N<sup>o</sup> 12*

*Effect of Heat on Catalase Activity*

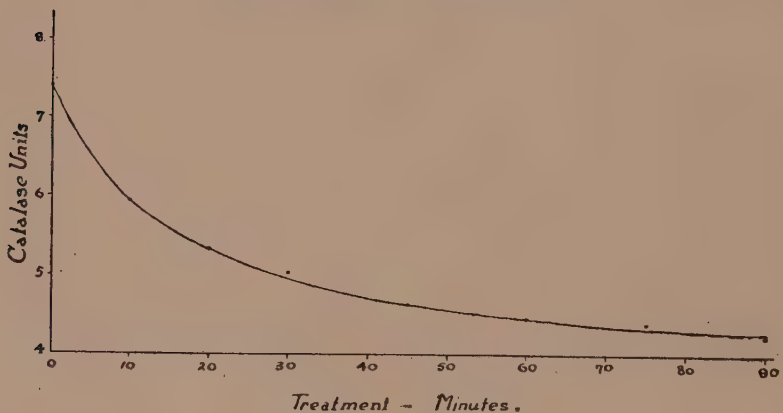


Figure 10.

It is clear from this graph that 20 minutes heating by no means destroys all the thermo-labile catalase but that the curve becomes very nearly horizontal after treatment for 90 minutes at which point there is a very considerable residue of catalase which must be considered as thermo-stable.

It seemed possible that the proportion of truly thermo-stable catalase in the seed might bear a relation to the viability of the seed. Series N 13 was therefore carried out, on the same plan as N 9 a, but in which all treated test samples were heated for 90 minutes at  $98^{\circ}\text{C}$ .

*Series N 13.* The samples used in this series are shown in table 12. Some of these are the same as those used in N 9 a, but are repeated here for convenience.

TABLE 12. *Samples used in Series N 13.*

Sample	Germ. 12 days	Remarks	Degrees of frost to which subjected
D-16-20	8	Mealy-dough, wet.	13
65-1997	22	Badly frosted and weathered.	Exact degree unknown.
D-11-21	34	Clear green.	14
B-11-21	36	Yellow kernel.	6.5, 14.
C-11-21	65	Green-to yellow	6.5, 14.
C-12-21	71	Pale yellow.	6.5, 14.
65-6756B	73	Weathered.	{Frosted, but exact degree unknown.
65-6756A	77		
65-6501	80	Weathered, plump.	"
65-6883	87	Uneven maturity.	Some frost.
#1	95	{1926 Reg. Crop, very high quality, but maintained at R.H. 71% several months.	0.
D-7-20	97		
A-16-20	100		

(Notes on those samples where exact degree of frost given (except #1) made by the University of Alberta at time of harvesting.)

Results in this series have been calculated to catalase units and, on account of the great differences in individual catalase activities, have been expressed as the ratio of thermo-stable to total catalase in the form of a percentage. These are shown graphically in Figure 11.

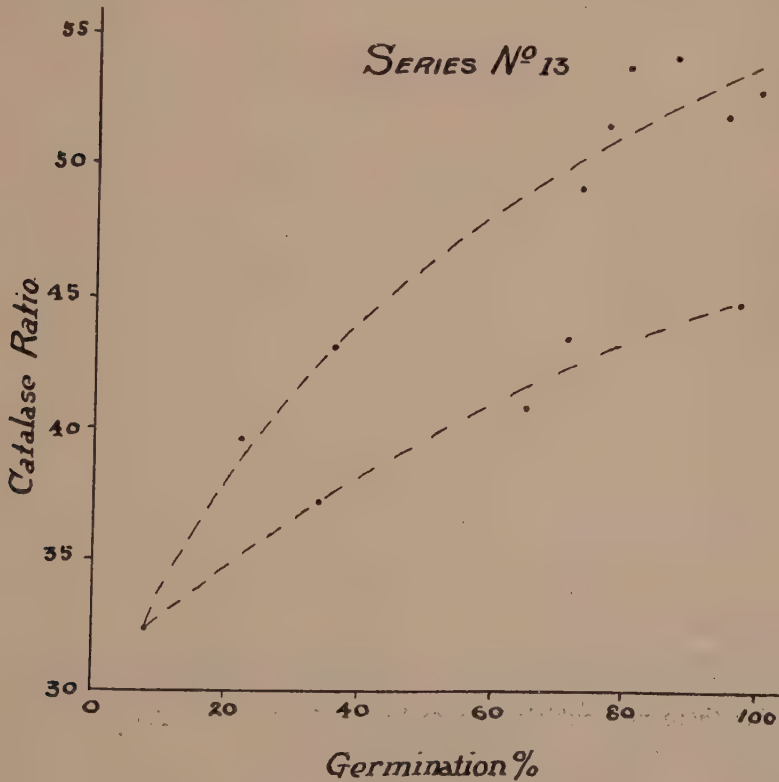


Figure 11.

While there is not the close correspondence it had been hoped to secure between this catalase ratio and the germination of the seed, yet on the whole, the samples of low viability show markedly lower ratios than those of high viability.

However, the points on this graph are seen to lie more or less in two zones, a lower and an upper, as indicated by the dotted curves. If we take the samples represented by the points near each curve and tabulate them separately as in table 13, an interesting and possibly significant point becomes evident.

TABLE 13. *Samples showing relatively high and low catalase ratios, tabulated separately.*

Sample	Germ.	Ratio	Total Catalase
<i>Samples showing high catalase ratios.</i>			
D-16-20	8	32.4	8.01
65-1997	22	39.6	6.62
B-11-21	36	43.1	5.75
65-6756B	73	49.3	6.80
65-6756A	77	51.7	7.56
65-6501	80	53.9	6.21
65-6883	87	54.3	8.20
#1	95	52.1	7.78
A-16-20	100	53.0	5.83
<i>Samples showing low catalase ratios.</i>			
D-16-20	8	32.4	8.01
D-11-21	34	37.2	14.98
C-11-21	65	40.8	10.94
C-12-21	71	43.5	10.55
D-7-20	97	44.9	14.51

In the last column the total catalase activity of each sample is shown. One sample (D-16-20) finds a place in both curves. Now all the samples in the group showing low catalase ratios, except D-16-20, were such as exhibited such high total activity that the amount of material tested had to be reduced to 0.1500 gms. in order that the burette might accommodate the oxygen liberated. It has previously been shown that high total catalase activity is associated with immaturity of the seed at the time of harvesting, hence this is an important point to be considered in the interpretation of results.

#### DISCUSSION

This method appears to be capable of being developed into a useful accessory to the germination test, but a considerable amount of further study is required.

Not all samples may lose their thermo-labile catalase in the 90-minute heating period, in which case those which gave an unduly high ratio might be brought more into line with the others. (The sample used to test the loss of thermo-labile catalase was a well matured frost-free sample of good quality, of which there was sufficient to make all the tests required.)

Relative degrees of immaturity of the seed introduce a complication which may require the introduction of a correction factor in order that all samples may be compared on an equal basis.

While the dry method developed is not entirely reliable for the direct comparison of catalase activity between samples, this is not of much moment when the comparison is to be made between treated and untreated test samples taken from the same grind, for replicates of any one grind show quite close correspondence. Where direct comparison between samples is required this may be done by preparing two or more grinds from each sample.

#### SUMMARY

That the germination method of testing seed viability requires a considerable time before the results can be known, is apt at times to be a serious hindrance to trade.

This has led investigators to turn their attention to finding an index of seed viability other than that of germination. Among the methods proposed, that making use of the catalase reaction has been chosen for study. Literature on these methods, and on the catalase reaction in general, has been reviewed and summarized.

This study has been confined to one kind of seed, viz., spring wheat.

Two methods of preparing the experimental sample have been tried—a wet and a dry.

In the wet method, the time of maceration adversely affected catalase activity, but centrifuged aliquots maintained their activity unimpaired up to one hour. Centrifuging for thirty minutes at 1000 revolutions was necessary to bring all samples to a stable condition of activity.

A dry method was finally adopted as more suitable. The catalase activity, however, was shown to be inversely proportional to the time of grinding, which necessitated the adoption of a standard time for grinding.

The depressive effect of excess of peroxide reported by other workers was observed.

The speed of shaking during the reaction was found to affect the activity, but this was more marked in the earlier stages of the reaction, and with a great difference in shaking speeds.

A graph in which oxygen liberated is plotted against catalase units was prepared and used in correcting for the depressive effect of excess of one or other of the reacting substances.

An attempt was made to duplicate Nemec and Duchon's work, but without securing the same results. It was observed, however, that not all the thermo-labile catalase was destroyed by heating for 20 minutes at the temperature of boiling water, and a series of experiments showed that this destruction did not occur until after about 90 minutes of such treatment.

A fresh series of experiments in which samples of different viability were tested before and after this 90-minute treatment showed a certain measure of correlation between the ratio thermo-stable: total catalase and viability. A graph on which the catalase ratio was plotted against the germination showed the points plotted to be arranged more or less in two zones, in one of which the catalase ratios were proportionately much lower for their corresponding germinations than in the other, but in each of which there was a fairly good relationship between the catalase ratio and germination. The

lower set of ratios were shown to be associated with samples having a considerable degree of immaturity and exhibiting high total catalase activity in consequence. The question of immaturity as affecting the catalase ratio is one requiring further study.

I have great pleasure in expressing my thanks to Dr. R. Newton, Professor of Field Crops and Plant Biochemistry, University of Alberta, under whose guidance this work has been undertaken, and to Dr. J. W. Campbell, Professor of Mathematics, for help in the mathematical parts.

I have great pleasure also in acknowledging my indebtedness to Dr. F. T. Wahlen, Chief of the Laboratory Division, Dominion Seed Branch, and to the Dominion Department of Agriculture for arranging facilities in time and equipment for carrying out this work.

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## FLAVOUR DEFECTS IN HIGH GRADE MILK

WILFRID SADLER †

*The University of British Columbia, Vancouver, B.C.*

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A little over a year ago, sixteen customers of a reputable milk company in the city of Vancouver refused to accept the milk with which they were being supplied. They complained that the flavour was undesirable and disagreeable. Samples of the milk were brought to our laboratories for examination. One sample was new raw milk that had just been bottled for distribution. The other sample was pasteurized milk of the same original supply and, although four days had elapsed since the pasteurizing, the milk had failed to clot as yet. There was "something" to be detected in the flavour of the four-day-old pasteurized milk; but what that "something" was we could not define. To a lesser degree the same condition was found in the raw milk. A little milk from each sample was transferred to sterile milk in erlenmeyer flasks—sufficient inoculations being made to permit of incubation at both 23°C. and 30°C. In due course, a clot was formed in each flask. Microscopically, the prevailing organisms proved to be Gram positive streptococci and diplococci. No yeasts or torulae cells could be found on the slides. In every case the flavour of the inoculated milk was decidedly unpleasant, somewhat nauseating and difficult to define. The odour was pungent and, in one instance, not unlike that of weak vinegar.

The company that consulted us considered the farmer from whom the milk in question came to be one of its best suppliers and, from experience, had been led to look upon his product as being a high grade milk. Even so, as far as I could gather, no actual figures on the bacterial count of the milk were available. The case presented certain interesting features and appeared to merit further attention.

Moreover, the condition of the milk samples recalled to mind a number of exhibits of milk that I had assisted in examining but a short time before in the Province of Alberta. In connection with the 1928 Convention of the Alberta Dairymen's Association (1), a milk and cream competition had been instituted and, in the judging of the exhibits, it was my happy lot to be associated with Dr. E. G. Hood of the Research Laboratories of the Dominion Dairy Division. When employing the Methylene Blue Reductase Test, we found that not a few of the samples of milk failed to decolorize the methylene blue after an incubation period of five and one half hours, thereby being rated as representing high grade milk. Later, when we came to judge the flavour of the same exhibits, that of a number was flat, insipid and not attractive. Apparently, the samples were at the stage where, in the words of Orla-Jensen, they had acquired "a slightly unpleasant smell and taste which may be described as 'stale'" (2). Neither Professor C. P. Marker, nor those of the Provincial and Dominion staffs who were assisting us, could be any more specific than could we in the defining of the flavour of these samples. The official descrip-

† Professor of Dairying.

tion remained, therefore, "flat and insipid." That in the samples under examination there might be few of the true lactic-acid-producing bacteria which predominate in so-called "Market milk" was a possibility. But it was not overlooked that in high grade milk there are certain bacterial strains which, unable to ferment the milk sugar rapidly enough to give pronounced acidity, can and do produce quite undesirable flavours. In view of this experience in Alberta it is readily to be seen that local material such as the raw and pasteurized milk samples brought to the laboratories would be welcomed.

#### THE "RAW" AND "PASTEURIZED" SAMPLES OF MILK

There was the possibility that the source of the undesirable flavour attributed to these two samples of milk might be found on the farm, and that therefore, the raw milk might be affected before it arrived at the receiving depot of the milk company. We made such recommendations as the circumstances seemed to suggest, advised that a suitable farm sterilizer—the one designed by Golding (3)—be installed by the producer, and that an examination of the company's entire plant be undertaken. Directed by my associate, Professor N. S. Golding, a senior student\* made a bacteriological examination of the milk cans, and of the machinery in use at the city milk depot. The results indicated that the "plant" was in a satisfactory condition. The producer installed the farm sterilizer as we had suggested and, at the instance of Mr. Fleming of the British Columbia Jersey Breeders' Association, he made some changes in the feeding of his cows. The net result of this plethora of advice was that the trouble ceased. No more customers were lost, and those that remained appeared to be perfectly satisfied with the milk they got.

Meanwhile, a laboratory examination of the milk samples brought to the laboratories had been begun. Lactose-gelatine plates were made of both samples of milk. In view of the age of the pasteurized milk, no attempt was made to determine the total bacterial content—bacterial colonies per c.c.—of either sample. The object was more especially to secure, if possible, the bacterial strains which predominated. Within 72 hours at 23°C., the plates showed growth and, on account of the presence of liquifiers, a number of colonies were picked. After the usual repurifications, five strains were finally retained:—Cultures Sm<sub>2</sub>, Sm<sub>3</sub>, Sm<sub>4</sub>, Sm<sub>5</sub> and Sm<sub>9</sub>. The strains Sm<sub>2</sub>, Sm<sub>3</sub> and Sm<sub>9</sub> were from the pasteurized milk; Sm<sub>4</sub> and Sm<sub>5</sub> were from the raw milk.

#### FLAVOUR AND ODOUR TRIALS IN MILK

The organisms were inoculated into flasks of sterile milk—milk sterilized by being submitted to flowing steam for three successive days—, were incubated, and examined with the results as shown below:

*Culture Sm<sub>2</sub>* (from the Pasteurized Milk).

Smell suggestive of faint caramel; flavour acid, slightly citrous, yet flat and insipid, yeasty and as *fresh dough*.

*Culture Sm<sub>3</sub>* (from the Pasteurized Milk).

Sweet slightly caramel smell; aromatic; flavour slightly caramel but not very definite. Clot formed in one day at 23°C.

\*Mr. Keith Thorneloe.

*Culture Sm<sub>4</sub>* (from the Raw Milk).

Odour not unpleasant but sweetly nauseating; flavour indefinite. No clot after four days at 23°C.

*Culture Sm<sub>5</sub>* (from the Raw Milk).

When first isolated: odour slightly caramel, possibly vanilla, yeasty; flavour flat, insipid, yeasty and as *fresh dough*. After having been in pure culture for eight months—odour yeasty and like dough after three days in milk at 23°C; flavour unpleasant, flat, insipid, not acid; after five days, flavour sharp acid and a little bitter; specifically as *sour dough*.

*Culture Sm<sub>9</sub>* (from the Pasteurized Milk)

Odour not unpleasant yet sweetly nauseating; flavour slightly metallic; on tasting no acidity to be detected after three days at 23°C., but an astringent effect is produced on the palate. Clot formed in five days at 23°C.

Some interest attaches itself to the *dough* flavour produced in milk by Culture Sm<sub>2</sub> and Culture Sm<sub>5</sub>. A member of the staff—let us say Mr. X—of the company whose milk we are considering, had had a number of years' experience as a grader. When customers began to complain of the milk which was later brought to our laboratories, Mr. X. was asked to grade it in the light of his previous experience. At the time, he defined the flavour as *feed* flavour. I asked Mr. X, when he called at the laboratory, to taste the milk that had been inoculated with pure cultures isolated from the "raw" and "pasteurized" samples. He agreed with us that some of the cultures gave a *dough* flavour. Further, he observed that this *dough* flavour, in his judgment, correctly described what hitherto he had defined as *feed* flavour. The question arises—may it be that flavours commonly called *feed*, for the sake of a better term, are, more often than is generally accepted, caused by specific bacteria? The five strains were now submitted to a more detailed cultural study.

## THE CULTURAL STUDY

*Media and Methods Employed:—*

Peptonized Milk Agar (Difco)	The Digestive Ferments Co. (4)
Nutrient Agar (Difco)	" " (4)
Nutrient Gelatine (Difco)	" " (4)
Sugar Gelatine: nutrient gelatine (Difco) to which glucose at the rate of 1 per cent was added prior to sterilization.	

Nitrate Agar (Difco) (4): employed as according to Manual of Methods (5).

Broth for Sugar Fermentations: the casein-digest broth of Orla-Jensen (6) was employed as the base.

To 3000 c.c. ordinary tap water are added 280 grams sugar-free commercial acid casein, 8 grams pepsin and 36 c.c. concentrated HCl. With frequent shaking for the first few days, the whole is allowed to digest for 10 days at 38°C. The digest is then filtered, made up to 2500 c.c. with water, and to it are added 10 grams K<sub>2</sub>HPO<sub>4</sub> and 5 grams MgSO<sub>4</sub>. This broth, double strength, is now neutralized, 10 c.c. of the double strength broth titrating to 1.9 to 2.1 c.c. of N/4 NaOH—pH 6.8—, is sterilized, and is kept until required.

As required for sugar determinations the broth is diluted with an equal amount of water, is cleared with egg white and the respective sugar broths are prepared, each sugar being added at the rate of 2 per cent. The various sugar broths are then tubed, 10 c.c. in each test tube, and are sterilized at 13 lbs. pressure for twenty-five minutes.

After sterilization the inoculations from the cultures are made, the whole series, with controls, being incubated at the proper temperature for 14 days. The sugars are titrated against N/4 NaOH with phenol-phthalein as indicator, the titrations of the controls are deducted, and the results are worked out and recorded as grams lactic acid per mille. In the present study the cultures in the sugar broths were incubated at 23°C.

Milk: for quantitative titrations for acidity—skim milk was tubed in 10 c.c. quantities and was sterilized at 14 lbs. pressure for 20 minutes.

Catalase Production: according to Orla-Jensen (2).

The work on the cultures is incomplete. Certain determinations, in some instances critical determinations, have not been made. Even so, yet with diffidence, I propose to submit as a record such data as may be available.

After Orla-Jensen (6) the total acid produced by the cultures in milk, and in the eighteen carbohydrates he employs, has been determined. The organisms have been grown in nutrient gelatine and in sugar gelatine. The results recorded are to be found in the table, page 119.

When the above-mentioned determinations had been made, the work was interrupted for some months. On resuming, it was found that *Cultures Sm<sub>2</sub>* and *Sm<sub>3</sub>* could not be revived. The study of the remaining three cultures, however—see table—has included observations on the morphology, the growth on nutrient agar, the ability of each strain to reduce nitrates to nitrites, and the ability or otherwise of each to form catalase. The nitrogen determinations—the amount of soluble nitrogen and amino nitrogen formed respectively—have been made on *Cultures Sm<sub>5</sub>* and *Sm<sub>6</sub>* only. The results as given in the table are expressed in terms of per cent of the total nitrogen present.\*

#### THE CLASSIFICATION OF THE CULTURES

For reasons that will be apparent, no suggested classification of three of the strains, *Cultures Sm<sub>2</sub>*, *Sm<sub>3</sub>* and *Sm<sub>4</sub>* is submitted.

##### *Culture Sm<sub>2</sub>*:

The notes made on the morphology of the strain when it was first isolated have been lost. The only information that can be made available is the description of the flavour produced in milk, page 113, and such reactions as are included in the table. The amount of acid produced by the organism in many of the carbohydrates is to be observed, and in particular must one note its activity in starch.

##### *Culture Sm<sub>3</sub>*:

Microscopically, in milk culture, this strain appeared as a Gram positive coccus, sometimes occurring in twos but not in chains. As will be seen from the table, the organism is very active in a number of the sugars, and is a strong starch fermenter.

##### *Culture Sm<sub>4</sub>*:

Microscopically—24 hours on peptonized milk agar at 23°C.—this strain is a small thin rod 1 x 0.3 microns in size. On staining by Gram, the cells can be observed, but more faintly than are the cells of a typical Gram positive organism; staining by Gram is inconclusive. While the culture is inactive in milk, and in most of the carbohydrates employed, it is a strong fermenter of xylose, glucose and galactose. To the data included in the table may be added the observation that the reaction for the production of catalase is quite violent.

##### *Culture Sm<sub>5</sub>*:

Microscopically—24 hours on peptonized milk agar at 23°C.—, this strain is a Gram positive coccus, 0.5 micron diameter, occurring as single cells and in masses. The staining is irregular, some cells being very definitely Gram

\*For these most important determinations, made at the Agricultural Experiment Station, Geneva, N.Y., thanks to the courtesy of Professor R. S. Breed and Professor G. J. Hucker, I am much indebted to Mr. Paul Arne Hansen.

positive, some not retaining the stain so well. On nutrient agar, growth is to be seen in the stab, while the surface growth is luxuriant, and is yellowish brown in color; according to Ridgway (7) pale orange yellow to warm buff and buff yellow. Both nutrient gelatine and sugar gelatine are liquefied rapidly—stratiform liquefaction. Nitrates are reduced to nitrites and the reaction for catalase production is active and violent. The production of acid in milk is comparatively slight and, with one or two notable exceptions, the sugars are but feebly fermented. One characteristic of the organism deserves an especial mention: its ability to produce a definite *dough* flavour in milk. Considered in the light of the work of Hucker (8, 9) on the *Micrococci*, *Culture Sm<sub>5</sub>* would appear to be a strain intermediate between *Micrococcus conglomeratus* Migula and *Micrococcus citreus* Migula; the former, according to Hucker (9), being probably one of the most common of the micrococci found in milk and milk products. As recently as 1928, using Hucker's key for identification, Alice Breed (10) has found that both *Micrococcus conglomeratus* and *Micrococcus citreus* are strains occurring in the normal udder of the healthy cow. The probability of *Culture Sm<sub>5</sub>* being an udder type is of some significance.

Approached from another angle, the characteristics of *Culture Sm<sub>5</sub>* suggest that it may rightly find its place within the genus *Tetracoccus* after Orla-Jensen (6).

In "The Lactic Acid Bacteria" (6) Orla-Jensen speaks of his genus *Tetracoccus* as follows: "In this genus I include all sugar-fermenting micrococci and sarcinae.....The quantity of lactic acid was in many cases so small that we were not able to determine with certainty of what sort it was. As they thus stand at the limit of what we will term lactic acid bacteria, we have not sought for them systematically, as for the cocci already described, and thus make no claim to have found, even approximately, representatives of all species belonging thereto, but merely of some of those most frequently met with in the dairy." In speaking of the habitat of the strains included in his genus *Tetracoccus*, Orla-Jensen (6) observes that tetracocci predominate in cow dung, that they are to be found in fresh cows' milk, in certain freshly made cheeses and also in the highly heated Emmenthal cheese. The rotary power of the lactic acid formed by *Culture Sm<sub>5</sub>* has not been determined. The ability of the strain to break down the nitrogen is specific, but not so marked as is the protein-splitting property of certain of Orla-Jensen's *Tetracoccus* strains which liquefy sugar gelatine: *Tetracoccus* Nos. 9, 10 and 11 respectively. *Tetracoccus* No. 10, *Tetracoccus liquefaciens*, is the strain to which *Culture Sm<sub>5</sub>* most clearly allies itself, even though the latter ferments mannite and the former does not, and the former is more active in the breaking down of the nitrogen than is the latter. It is proposed, therefore, to place *Culture Sm<sub>5</sub>* within the genus *Tetracoccus* of Orla-Jensen; although the organism might appear to be equally at home as a strain intermediate between *Micrococcus conglomeratus* Migula and *Micrococcus citreus* Migula after Hucker (9). Placed in the genus *Tetracoccus*, the suggestion naturally follows that *Culture Sm<sub>5</sub>* is to be considered as a *Tetracoccus liquefaciens* Orla-Jensen (6) strain.

*Culture Sm<sub>3</sub>:*

Microscopically—24 hours on peptonized milk agar at 23°C.—, the organism is a Gram positive coccus, 0.8 micron diameter, occurring in twos, in masses and characteristically in tetrads. On nutrient agar there is a luxuriant white surface growth with some growth in the stab. Both nutrient gelatine and sugar gelatine are liquefied rapidly, the type of liquefaction being infundibuliform. Nitrates are reduced to nitrites, and the reaction for catalase is active and violent. Like *Culture Sm<sub>3</sub>* this strain, in the main, is a feeble sugar fermenter; unlike *Culture Sm<sub>5</sub>* it fails to produce any acid from mannite. *Culture Sm<sub>3</sub>* does not produce the *dough* flavour in milk, but there is peptonizing of the clot. On the sum of the characteristics determined, the strain would appear to find a place within the genus *Tetracoccus* of Orla-Jensen (6). Hucker (11) observes that the tetracocci of Orla-Jensen which produce a definite acid-proteolysis in milk are generally white and that the tetracocci producing a white growth on agar and acid-proteolysis in milk are identical with his *Micrococcus casei*, now *Micrococcus caseolyticus*, Evans. Evans (12), and more recently Alice Breed (10), have found *M. caseolyticus* Evans (*M. casei*, Hucker) to be common strains in the normal udder of the healthy cow. It would appear to be equally sound, therefore, to place *Culture Sm<sub>3</sub>* as within Orla-Jensen's genus *Tetracoccus* (6) or as a variant of *M. caseolyticus* Evans after Hucker (11). If one is to follow Orla-Jensen it is to his *Tetracoccus* No. 9 or *Tetracoccus* No. 10, each *Tetracoccus liquefaciens* Orla-Jensen (6), to which *Culture Sm<sub>3</sub>*—a strain which gives a white growth on agar, reduces nitrates to nitrites, produces catalase and rapidly liquefies both nutrient and sugar gelatine—should ally itself. *Culture Sm<sub>3</sub>*, however, fails to break down the nitrogen to the extent which characterizes either *Tetracoccus* No. 9 or *Tetracoccus* No. 10, a quite noticeable if not specific divergence. Even so, it is proposed to classify *Culture Sm<sub>3</sub>*, a strain closely allied to *Micrococcus caseolyticus* (Evans) after Hucker (11), as of the type *Tetracoccus liquefaciens* Orla-Jensen (6).

## OBSERVATIONS

The most striking observation that suggests itself is the possibility that both *Culture Sm<sub>5</sub>*—one of the strains that produces the undesirable flavour in milk—and *Culture Sm<sub>3</sub>*, are udder types and that the organisms were present in the milk at the time it was drawn from the cow. On the other hand, the strains may have come from the manure. Either or both of these sources may be taken as a probability and, in any case, the work suggests that caution must be observed in the producing and managing of high grade milk, i.e., milk having a low bacterial content. The mere fact that high-grade milk may fail to sour, even after several days, is no argument that such milk can be kept for several days and still be suitable for consumption\*. Bacteria which are feeble sugar fermenters are present, as has been shown in the present paper (see *Cultures Sm<sub>5</sub>* and *Sm<sub>3</sub>*), and certain of these feeble sugar fermenters are producing disagreeable flavours (see *Culture Sm<sub>5</sub>*). It is of the utmost importance that encouragement be given to the production of an ever-

\*Already it has been observed by Orla-Jensen (2) that ".....it is not advisable to keep milk longer than twenty-four hours, even if cooled to 0°C.; .....cooled milk or cream which has stood for any length of time is to be regarded with suspicion, even if apparently unchanged."

increasing supply of high-grade milk. It is of equal importance to recognize that even high-grade milk is not bacteria-free and that, unless such milk be consumed within a reasonable interval after production, it may be unpalatable in flavour and unsuitable for consumption. The bacteria always found in the healthy udder of the cow show little evidence of their presence when, as in the so-called market milk, there are to be found many of the typical lactic-acid-producing bacteria, the common milk souring organisms. But, when methods are improved to the point where we can produce a milk so low in bacterial content that few lactic acid bacteria are present, the udder bacteria assume a new importance, for they have almost a clear field for growth and multiplication. That some vigorous sugar-fermenting strains were present in the milk here reported upon is to be seen when one contemplates the characteristics of *Cultures Sm<sub>2</sub>* and *Sm<sub>3</sub>*. Further it is to be observed that *Culture Sm<sub>2</sub>*, a strong sugar fermenter gave, as did *Culture Sm<sub>5</sub>*, a feeble sugar fermenter, the flat, insipid, yeasty, *dough* flavour in milk.

It is not improbable that the original defect in the flavour of the milk might have been due to the action of vigorous sugar-fermenting strains such as *Culture Sm<sub>2</sub>*, and to strains of feeble sugar fermenters such as is *Culture Sm<sub>5</sub>*.

Another consideration merits attention. It has been shown that among the bacteria isolated from the milk samples examined are some which give a definite *dough* flavour in milk, a flavour which, by a competent and experienced grader, had been defined as *feed* flavour.

#### SUMMARY

Samples of milk having a disagreeable and undesirable flavour have been examined. The flavour was indefinite and difficult to define. Of the organisms isolated in pure culture for study, two strains produced a flat, insipid, yeasty, *dough* flavour in milk. One of the two strains, *Culture Sm<sub>2</sub>*, was a strong sugar fermenter. This organism died before all its characteristics were determined. The other of the two strains, *Culture Sm<sub>5</sub>*, is feeble in its fermenting of the sugars.

Two cultures have been studied in some detail: *Culture Sm<sub>5</sub>*, a feeble sugar fermenter, which produces the flat, insipid, *dough* flavour in milk, and *Culture Sm<sub>9</sub>*, also a feeble sugar-fermenter, which fails to produce the *dough* flavour in milk. Both these cultures are strains which may be encountered in the bacterial flora of the healthy udder of the cow, in cow manure, and in certain types of cheese. A discussion on the characteristics of *Cultures Sm<sub>5</sub>* and *Sm<sub>9</sub>* is presented, and each is classified as a *Tetracoccus liquefaciens* (Orla-Jensen) strain. Comments are made on the apparent significance of the work in dairy practice.

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TABLE

No.	Isolated from	Milk										Liquefying		Reduction of Nitrates	Catalase Production											
		Glycerine	Xylose	Arabinose	Rhamnose	Sorbitol	Mannite	Laevulose	Glucose	Mannose	Galactose	Saccharose	Maltose			Lactose	Raffinose	Inulin	Dextrin	Starch	Salicin	Time of Curdling Days	Amount of Acid	Sol. N. % of Total N.	A.N.	N.G.
	III-Flavoured Milk																									
Sm <sub>2</sub>	Pasteurized	(a) 0.7	0.7	1.6	2.5	—	4.3	6.0	6.0	5.75	4.1	4.6	5.4	4.7	4.8	—	2.5	3.4	3.05	—	5.75	—	—	—	—	Not done
Sm <sub>3</sub>	Pasteurized	0.7	0.9	6.0	0.6	0.7	4.1	6.2	6.2	6.2	4.1	1.6	5.3	5.4	0.6	0.7	1.6	3.9	3.6	1	7.55	—	—	—	—	Not done
Sm <sub>4</sub>	Raw	0	4.3	0	0	0	0	0	4.5	2.7	3.6	0	0	0	0	0	0	0	0	—	0.2	—	—	—	—	+
Sm <sub>5</sub>	Raw	0.7	—	0.35	0.35	0.1	2.5	2.9	2.7	1.8	1.9	3.3	2.5	4.3	1.5	0.2	1.1	1.25	0.9	3	3.5	32.5	8.3	(b) +	+	(c) +
Sm <sub>9</sub>	Pasteurized	0.9	0.7	0	0	0	0.2	2.9	3.2	1.6	3.2	2.5	3.8	3.4	0.2	0.2	0.2	0.9	0.2	5	3.4	19.2	0.6	+	+	+

(a) Figures represent parts per thousand of lactic acid as determined by titration with N/NaOH. The arrangement of headings and the method of stating the results are the same as those used by Orla-Jensen (9).

(b) Liquefaction rapid, beginning in 24 hours at 23°C.; nutrient gelatine liquefied more rapidly than is the sugar gelatine.

(c) Very active in the decomposing of the  $H_2O_2$ ; entire tubes of milk displaced within 1 hour.

# A KEY TO CERTAIN TORTRICID LARVAE OCCURRING IN NOVA SCOTIA WITH NOTES ON THEIR HABITS AND LIFE-HISTORIES

F. C. GILLIATT

*Dominion Entomological Laboratory, Annapolis Royal, N.S.*

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Since 1926, when a study of certain lepidoptera belonging to the family Tortricidae was undertaken, several species, not previously known to be present were identified. These species, belonging to a group of insects known popularly as budmoths or leaf-rollers, are now known to be fairly well distributed over the entire fruit growing section of the Annapolis valley and in many districts are orchard pests of importance. There is a decided similarity among the larvae of some of these species. Not only do they resemble one another, but they also bear a striking resemblance to some of our better known budmoths; and those who are not pursuing a daily study of these insects find it difficult to make identifications from the larvae in the orchard. In some instances it is not desirable, or even possible, for identification to be based entirely on the habits of the insects or their effect upon the host plant. A simple key which will lead to the identification of the larvae more readily, may be of some assistance, not only to inspectors and workers in entomology, but also to observing orchardists. When the species has been established, the inspector is at once provided with a clue to the destructive ability of the insect and the most effective known methods of control are therefore suggested. It is unfortunate that all the species cannot be readily identified in their early stages for several of the species included in the following key are so similar that the author finds it almost impossible to present readily distinguishable characters. The accompanying key, therefore, has reference to mature larvae, or at least to their more mature stages.

## KEY TO COMMON BUDMOTH OR LEAF ROLLER LARVAE

### A. With shiny black head.

B. Body cinnamon brown; fully grown in  
June-July.....*Spilonota ocellana* D. & S.

BB. Body yellowish-green; fully grown in  
June-July.....*Archips rosaceana* Harris

BBB. Body bottle green or dark greenish-black;  
fully grown in early June.....*Argyroplote variegana* Hbn.

### AA. With pale green, or amber colored head.

B. Abdomen marked with a greenish dorsal  
stripe, and two lighter subdorsal stripes;  
Larvae mature in May and June.....*Cacoecia persicana* Fitch.

- BB. Abdomen not definitely striped.
- C. Tubercles concolorous with body, larvae fully grown in September-October.....*Eulia mariana* Fern.
- CC. Tubercles lighter in color than body surface; fully grown in June and July.....*Pandemis limitata* Rob.
- AAA. With brown or dull amber colored head.
- B. Body blackish or brown-pink with blackish irregular subdorsal stripes; fully grown in September-October.....*Tortrix afflictana* Wlk.
- BB. Body green; thoracic shield brownish or green, narrowly margined with brown or black; fully grown late in August-September.....*Amorbia humerosana* Clem.

Chart Showing Work of Common Budmoth and Leaf-roller Larvae on Foliage and Fruit of Apple.

SPECIES	WORK ON LEAVES	WORK ON FRUIT	HIBERNATION METHOD OF
<i>Spilonota ocellana</i> D. & S.	Bores into opening buds in spring, later ties the expanding leaves together in bunches; when excessively numerous destroys considerable leaf area. New generation appears in mid-summer skeletonizing leaves from under surface.	The larvae in early spring often bore holes in setting apples, which later form russet-like scars resembling green fruit worm injury. New generation fasten leaves to apple surface, and feeding between, produce numerous small excavations on surface of apple.	Small larvae in hibernacula.
<i>Archips rosaceana</i> Harris	Bores into opening buds in spring, later rolls a single leaf or draws several together and feeds upon surrounding foliage. New generation appears in mid-summer, seek some place of concealment and feed by skeletonizing the leaves.	The larvae, after emerging from hibernacula in the spring, consume portions of the setting fruit, resulting in scars similar to green fruit worm injury. The damage to fruit by new generation is similar to that caused by <i>S. ocellana</i> D. & S.	Small larvae in hibernacula.
<i>Argyroplote variegana</i> Hbn.	Bores into opening buds in spring, later rolls or ties several leaves together in large bunches. They consume whole portions of the leaves and when numerous cause a very bunched appearance with considerable reduction of leaf area. New generation skeletonizes the foliage, but due to their brief feeding period the damage is not readily observed.	The larvae have not been observed attacking fruit in the spring. New generation occasionally fastens leaves to fruit causing side injury, but due to the brief feeding before hibernating, this injury is insignificant to that caused by other insects of this group.	Small larvae in hibernacula.

SPECIES	WORK ON LEAVES	WORK ON FRUIT	METHOD OF HIBERNATION
<i>Cacoecia persicana</i> Fitch.	On emerging in spring ties one or more leaves together, consuming leaves chiefly at margin. New generation enters some place of concealment, such as old webs of bud-moth ( <i>S. ocellana</i> D. & S.), later tying leaves to surface of fruit.	Larvae which have hibernated through the winter do not attack fruit in the spring. New generation after tying leaves to fruit feeds on surface producing shallow excavations or irregular paths.	Half-grown larvae in fallen leaves.
<i>Eulia mariana</i> Fern.	The young larvae skeletonize the foliage from the under surface; when about half-grown they begin to migrate and fasten together two or more leaves in a loose bunch, feeding upon the margins.	The larvae conceal themselves about the fruit and feed upon the surface causing shallow excavations which may involve as much as one-half the surface of the apple.	Pupae in fallen leaves.
<i>Pandemis limitata</i> Rob.	Enters buds in spring, later tying leaves closely together and feeding in a similar manner to <i>C. persicana</i> Fitch. New generation also enters old webs of budmoths. and later tie leaves to fruit.	Larvae have not been observed to feed upon the fruit in the spring. New generation after tying leaves to fruit make small circular, usually purple rimmed holes which occur singly or in twos or threes, occasionally larger numbers.	Small black-headed larvae in hibernacula.
<i>Amorbia humerosana</i> Clem.	So far observed the larvae of this species feed throughout their entire growth by folding over one leaf or drawing two or more together in the familiar tortricid manner, feeding upon the margins.	The larvae of this species have not been observed feeding upon the fruit.*	Pupae in fallen leaves
<i>Tortrix afflictana</i> Wlk.	The young larvae seek some place of concealment, especially old bud-moth webs. Later their leaf-feeding habits are similar to <i>A. humerosana</i> Clem.	This species, though not numerous, has on several occasions been observed feeding upon the fruit, causing deep irregular holes upon the surface.	Mature larvae in fallen leaves.

\*AUTHOR'S NOTE: Since the above was written the larvae of *Amorbia humerosana* Clem. have been observed feeding upon the surface of the fruit in several apple orchards situated in the western part of the Annapolis valley. The scars produced were pronounced, involving a considerable portion of the surface of the apple.

## LIFE-HISTORY NOTES

As a brief life-history of these insects has been published elsewhere by the author, only a grouping outline will be narrated here.

Under Nova Scotia conditions *Archips rosaceana* Harris, *Pandemis limitata* Rob., *Argyroplote variegana* Hbn., and *Spilonota ocellana* D. & S. pass the winter, as small partly grown larvae about one-eighth of an inch in length, in hibernacula upon the trees. These hibernacula are made of fine threads of silk spun by the larvae and when completed form a rather tough impervious protection during the winter. They are to be found under old bud scales, around buds, in the axiles of small twigs and in various other irregular depressions upon the smaller outer branches of the trees. When numerous they frequently form colonies of several larvae, which often contain more than one species, each larva in the colony, however, always spins and occupies its own individual cell. The larvae of these four species emerge in the spring when the buds begin to burst, and feed upon them as they unfold. In June and July they become mature and pupate in rolled up leaves upon which they have been feeding. Only a short time is spent in the pupal stage, the adults soon appearing to deposit their eggs. The eggs are laid upon the foliage, those of the first two mentioned species in masses, the latter two depositing them singly or occasionally in groups of two or three. The young larvae begin to appear upon the trees in July and August to complete a part of their growth before hibernating.

The feeding period of the new generation of *Argyroplote variegana* Hbn., *Archips rosaceana* Harris, and *Pandemis limitata* Rob. is quite brief. The first named species begins to hibernate during the last week of July and the latter two during the first part of August. It is somewhat different, however, with *Spilonota ocellana* D. & S. The new generation of this species remains upon the foliage for a longer time and the hibernating period is quite protracted. The more advanced larvae begin to seek winter quarters during the latter part of August and continue to hibernate irregularly during the month of September with a small percentage still remaining upon the foliage until well into October.

It can be readily observed, although there is only one generation a year of these insects, that the larvae do not complete their growth in the season in which they hatch, but continue to feed the following year before becoming mature.

*Cacoecia persicana* Fitch, like the above species, also hibernates as a partly grown larva, but in a more advanced stage, being about one-half an inch in length. In the early fall the larvae begin to desert the trees and after reaching the ground enclose themselves singly in the fallen leaves by sewing over one edge, and in such enclosure pass the winter. In the spring, as the buds begin to show development, the larvae emerge from their winter quarters and feed first upon weeds, grass, etc. This food is later largely discarded when they ascend the trees and feed upon the foliage in a manner typical of leaf-rollers. The larvae attain maturity in late May and early June, when the pupae are to be found under the rough bark on the trees and in dead leaves on the ground. The adults begin to appear about the middle of June,

depositing their eggs, which are laid in masses, on the foliage of the trees as well as on the smooth bark of the limbs. The larvae feed upon the foliage and fruit of the apple in a more or less concealed manner until early fall, when they begin to find their way to the ground prior to hibernation.

*Eulia mariana* Fern. and *Amorbia humerosana* Clem. both pass the winter as pupae rolled up in the fallen leaves upon the ground. The adults of both species emerge in the spring as the trees are coming into bloom, which is usually in late May or early June. Towards the end of June the young larvae begin to appear upon the foliage of the trees.

The larval period is very protracted, *Amorbia humerosana* Clem. pupating in late August and *Eulia mariana* Fern. not until September extending well into October. The larvae at this time find their way to the ground where they pupate as already indicated. There is only one generation in Nova Scotia.

*Tortrix afflictana* Wlk. passes the winter as mature larvae in the fallen leaves. Pupation occurs early in April and the adults emerge in spring to deposit their eggs, which are laid in masses, on the smooth bark of the trees. In 1928 egg masses were found in orchards early in June, which hatched on June 18. There is a long feeding period, the larvae not becoming mature until early fall. There is only one generation a year.

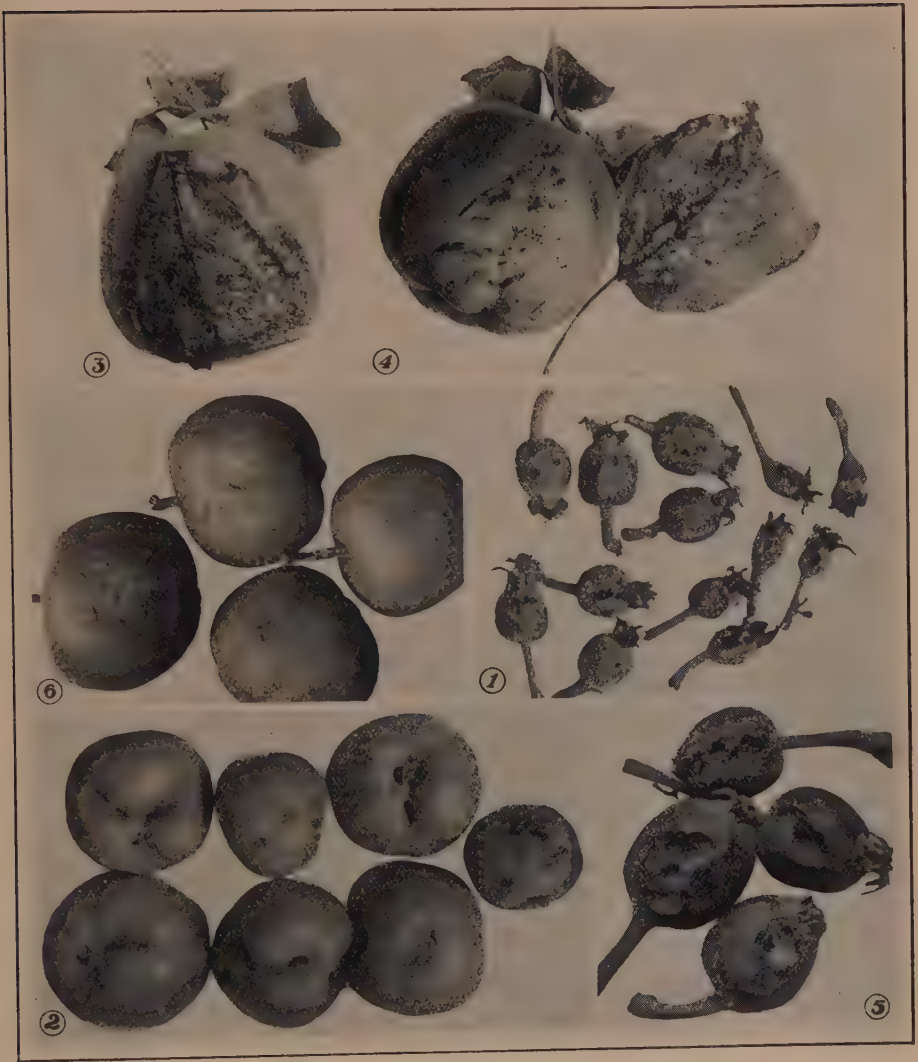


PLATE I.

- Fig. 1. Apples showing typical scars made by the larvae of *Spilonota ocellana* D. & S. at blossom time.
- Fig. 2. Apples showing mature scars produced by the spring feeding of *Spilonota ocellana* D. & S.
- Fig. 3. An apple showing how the leaves are tied to the fruit by the summer brood larvae of *Spilonota ocellana* D. & S.
- Fig. 4. Same as Figure 3, with leaf removed showing the fruit injured beneath.
- Fig. 5. Apples showing effect of the feeding of *Archips rosaceana* Harris' larvae soon after the petals have fallen.
- Fig. 6. Work of *Archips rosaceana* Harris showing injury to fruit by the newly hatched larvae in early fall.



PLATE II.

- Fig. 7. Apples showing scars or paths produced by the larvae of *Cacoecia persicana* Fitch.
- Fig. 8. Apples showing the small circular holes produced by the larvae of *Pandemis limitata* Rob.
- Fig. 9. Work of *Eulia mariana* Fern. showing the typical shallow late feeding of the larva.
- Fig. 10. Apple showing late feeding of *Tortrix afflictana* Wlk. This photograph does not indicate clearly the real depth of the injury.
- Fig. 11. Typical hibernaculum of *Spilonota ocellana* D. & S.
- Fig. 12. Hibernaculum opened to show larva within.



PLATE III.

- Fig. 13. Apple leaves tied together at terminal growth. The shelters thus formed are typical of many leaf roller larvae.
- Fig. 14. Typical bunched foliage produced by the larvae of *Argyroplote variegana* Hbn.
- Fig. 15. Apple foliage at blossom time infested with *Spilonota ocellana* D. & S. showing the typical bunched condition, as well as the partially consumed dwarfed foliage.
- Fig. 16. Eggs of *Spilonota ocellana* D. & S. laid singly on the under surface of an apple leaf. These are also typical of *Argyroplote variegana* Hbn.
- Fig. 17. Egg mass of *Archips rosaceana* Harris on upper surface of an apple leaf, which is also typical of many leaf rollers.

# THE ERADICATION OF WEEDS BY CHEMICAL AGENTS. A BRIEF REVIEW OF LITERATURE

WILBERT C. HOPPER †  
*Central Experimental Farm, Ottawa, Ont.*  
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It has been common knowledge for many hundreds of years that weeds, allowed to grow amongst agricultural crops, reduce crop yields. Consequently efforts have always been made to destroy them.

In 1557 Thomas Tusser in his "Five Hundred Points of Good Husbandry" advised:

"In May get a weedhook, a crotch and a glove,  
And weed out such weeds as the corn does not love;  
For weeding of winter corn, now it is best;  
But June is the better for weeding the rest."

The gardener in Shakespeare's Richard II (Act 3, Scene 4) says:

"I will go root away  
The noisome weeds that without profit suck  
The soil's fertility from wholesome flowers."

Other early writers on agriculture such as Jethro Tull (1731) and Thomas Hale (1756) recognized that weeds caused much loss to agricultural crops.

Vast numbers of weed eradication experiments have been conducted in America and in other parts of the world and thousands are under way today. Amongst the various measures used to rid cultivated and sod land of undesirable plants which rob plants of economic importance of moisture, plant food and light, applications of various kinds of chemicals take an important place.

About 1896 a French grape grower, L. Bonnet, while spraying his vines with Bordeaux mixture, found that the leaves of the mustard plants in the vicinity were blackened wherever the spray had fallen on them. It is believed that this is the origin of the use of sprays for weed eradication. This chance discovery was followed by experiments in France, Germany, Great Britain, and America.

The first man in North America to report experiments in the eradication of mustard with copper sulphate and iron sulphate was Shutt of Canada (13). It is believed that Bolley (1) was the earliest worker in the United States to try sprays. In addition to the materials used by Shutt he experimented with sodium chloride, corrosive sublimate and sodium arsenite.

In the last few years this chemical warfare against weeds has become more intense. The kinds of sprays have been greatly increased in number, and dusting and soil fumigation have also been resorted to as possible means of effective control.

In addition to the chemicals used by Bolley, petroleum oils (15), calcium chloride, sulphuric and hydrochloric acids, carbon bisulphide, ammonium sul-

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†Chief Assisant, Division of Field Husbandry.

phate, sodium and potassium chlorate, kainit, calcium cyanamid and many others of lesser importance have been used. Some of these have been applied as wet sprays to kill the aerial parts of the weeds and prevent seed formation, some have been used as "root absorption" sprays to kill seeds, roots and rhizomes, still others have been applied to change the soil reaction, while carbon bisulphide has been put into the soil in the hope that its vapor would kill the underground stems of field bindweed (*Convolvulus arvensis*) and weeds of similar habits (15).

Most of the chemical agents used to kill annual weeds are "selective", that is they injure or kill the weeds but leave the crop almost or entirely uninjured. "The reason for this," states Brenchley (2) "lies in the variable position, texture and surface of the two classes of plants, and consequently it is only with certain crops and weeds that the desired result can be satisfactorily obtained. Leaves that are covered with a waxy bloom or with a dense mass of fine hairs are very difficult to wet, as any liquid applied tends to collect into globules and roll off, especially if, in addition, the leaves are carried in a more or less vertical position. Broad outspread leaves, devoid of waxy bloom and bearing a certain number of short erect hairs, are easily wetted, as the liquid is caught and held by the hairs long enough to enable it to penetrate the tissues. In the same way dry sprays are thrown off by the first class more easily than by the second. Consequently cereal crops and such weeds as grasses and those with dense hairs are more or less immune, whereas certain broad leaved crops, as potatoes and sainfoin, and weeds such as charlock are very susceptible to various chemicals used as sprays. The popular idea is that narrow-leaved plants are immune and broad-leaved plants are susceptible, but this broad distinction is not quite true, as the hairiness, waxiness or smoothness of the leaves are all equally determining factors. This point needs careful consideration when spraying is contemplated, though it is not always possible to predict the immunity or susceptibility of any particular species of crop or weed without experimental trials."

#### CONTROL OF ANNUAL WEEDS IN CULTIVATED FIELDS

In England the most widely used chemical for weed destruction is copper sulphate, while iron sulphate is more popular in Germany and America. Both of these sprays have for many years been used to destroy such weeds as wild mustard in grain fields. The most suitable time for using them is when the weather is dull and humid without wind, and when a succeeding period without rain is anticipated. A hot sun is liable to cause the salts to crystalize before penetration has taken place, wind will not allow an even distribution of the spray, and rain occurring within a few hours of spraying is likely to wash off the poison before it has performed its work of destruction.

By far the greatest amount of spraying with iron and copper sulphate in America has been directed against the mustard plant. Little work of a successful nature in the eradication of other weeds has been reported in the literature. Members of the mustard family are perhaps the worst of our common annual weeds and splendid results in the eradication of wild mustard (*Brassica arvensis*), black mustard (*Brassica nigra*) and wild radish (*Raphanus raphanistrum*) with iron and copper sulphate have been reported.

The leaves of mustard plants are rough with scattered hairs which hold the spray well and spraying either kills the plants outright or prevents them from producing seed.

Some workers suggest that mustard should be sprayed when the plants are quite small with only three to five leaves. At this time the spray will come into contact with all parts of the plants. The main objection to spraying at this stage of growth is that more mustard seedlings may appear later, and if all the weeds of that year are to be caught with one spray it may pay to wait a week or so. In any event it is wise to spray before any of the plants have begun to bloom.

Experiments conducted on large fields at the Central Experimental Farm, Ottawa, Canada, in 1928 indicated that a solution of 8 pounds of copper sulphate to 40 gallons of water was very efficient in killing mustard in a badly infested oat crop. Some of the mustard plants were just coming into bloom but the majority were less mature. At this stage one application, at the rate of 50 gallons per acre, killed 98 per cent of these plants. Moreover, the cost of copper sulphate was only about \$1.00 per acre. Cloudy, humid weather prevailed at the time of spraying.

The application of 50 gallons of a solution of iron sulphate made up at the rate of 80 pounds to 40 gallons of water to the same field killed only 66 per cent of the weeds, but the inferior result as compared with copper sulphate may be due in part to less propitious weather conditions. The cost of iron sulphate to spray one acre was about \$3.00.

The amounts of copper and iron sulphate used in the above experiments are those most generally recommended for weed eradication.

Practically no injury to the oat crop was noticed nor did these solutions appear to injure appreciably the young clover plants to which the field had been seeded down at the time the oats were sown. The injurious action of iron and copper sulphate on the leaves of the mustard plants is not clearly understood.

While the mustard plants growing in any particular season may be destroyed by chemicals, spraying operations almost always have to be repeated the next season to kill the plants which grow from seeds remaining in the soil to germinate the following year. Often it takes several years to stamp out mustard from cultivated fields and in some rare cases complete eradication has seemed to be impossible.

In recent years sulphuric acid has come rather quickly to the front as a successful selective spray and in some countries has practically replaced the sulphates of iron and copper. In 1911 Rabaté (3) reported some results from experiments in weed eradication in winter wheat which mark the beginning of this new period. His applications of approximately 107 gallons per acre of 6, 8 and 10 per cent sulphuric acid solutions killed most annual weeds but did not retard the growth of the wheat, although the lower leaves were killed. The cutin layer on the leaves of the cereal prevented the sulphuric acid from adhering, and its concealed growing points were an additional protection. Rabaté stated also that the sulphuric acid solution had a fertilizing effect upon the soil.

Jaguenaud (4) found that sulphuric acid killed wild radish, wild mustard, crowfoot, vetches and vetching without injury to wheat.

Åslander (5) reports that Korsmo of Norway found that solutions with a strength of 3.5 to 4 per cent were sufficient to kill all annual weeds to which the spray could adhere. As a result Korsmo obtained a very marked increase in yield. From an average of 211 experiments conducted from 1914 to 1922 in spring-sown grain crops, Korsmo obtained an increase in yield of 25.3 per cent above unsprayed plots. Åslander has given a list of 53 weeds which have been reported killed by sulphuric acid solutions of different concentrations ranging from 3.5 to 10.0 per cent.

Very few perennial weeds have been injured by sulphuric acid because the roots have been unharmed. Spraying Canada thistle, however, has been found to prevent shoots from flowering, and Dehn (6) reports that a few drops of this acid applied to the crown of certain perennial weeds in lawns has been found to be a sure but slow method of eradication.

For the eradication of common mustard the sulphuric acid solution has found in America a most useful place. Åslander (5) has reported some carefully conducted greenhouse experiments where this spray was applied to mustard (*Brassica arvensis*). The most striking effects were: (1) after adhering to the surface of the plants the acid penetrated very rapidly and killed the protoplasm almost instantly, (2) it decomposed the chlorophyll by uniting with the magnesium atom of the chlorophyll molecule and (3) it broke up the chloroplasts. It was found that plants in the greenhouse were easily destroyed by a 2 per cent solution, while plants in the field (in England) required no less than 5 per cent to kill them. Analyses of the plants showed that those grown in the field had a far greater amount of dry matter, especially of ash, than the greenhouse plants. This suggested that the acid may have been partially neutralized by some of the constituents of the ash. The killing effect of sulphuric acid is very rapid, especially when the weather is warm and dry. Solutions of 3.5 to 5 per cent appear to be sufficiently strong for average conditions in the control of mustard and other weeds to which the spray will adhere.

In referring to the selective nature of the sulphuric acid spray, Åslander states that as the leaves of peas are rather waxy they are not injured by this spray. He observes also, that after clover plants have developed true leaves they too are uninjured by this spray. The true leaves have a protection of dense hairs. In some field experiments conducted at Ottawa, Canada, in 1928, 50 to 60 gallons of spray were applied per acre to destroy mustard plants in an oat crop. This quantity seemed to be sufficient. A potato sprayer was used to apply the spray. A spray with a 3.5 per cent concentration would be 1.4 gallons, (about 25 pounds) of concentrated sulphuric acid to a 40-gallon spray barrel. The wholesale price of sulphuric acid is about 5 cents per pound or about \$1.50 for sufficient to treat one acre. To this must be added the cost of mixing and applying. Considerable care must be used in handling sulphuric acid.

Sodium arsenite is another chemical which has been used fairly extensively in certain regions to kill weeds. Its value for this purpose has been

recognized in the Hawaiian islands, where it has been used on a fairly large scale to destroy weeds growing amongst pineapples (7). It has also been employed with some success in the control of wild morning glory (8). In small amounts sodium arsenite has been utilized in many places to kill all vegetation along roadways, sidewalks, fences, etc. Under these conditions it has a distinct value. In Canada and in the United States this chemical has not found much favor for the eradication of weeds except in situations where all growth is to be destroyed. Soils possess a strong fixing power for arsenic and when a sodium arsenite spray is applied to destroy weeds the arsenic will ultimately be deposited in the surface soil, there to remain in spite of the leaching effect of rains or irrigation. On soil so treated it is usually impossible to produce crops for a year or more.

#### DUSTS OR "DRY SPRAYS"

Brenchley (2) states that the application of kainit has been employed in parts of Europe as a "dry spray". This material has the advantage of supplying a useful proportion of potash to the soil. Its killing properties are attributed to plasmolytic action on plant cells, water being withdrawn from the cells to help to dissolve the kainit held on the leaves by dew. It is essential that the kainit be very finely divided so that 50 per cent will pass through a  $\frac{1}{4}$  mm. sieve. Best results are obtained when fine dry kainit is evenly distributed in adequate quantities over young plants moist with dew and the sprinkling occurs in dry conditions followed by a sunny day and a cool dewy night. It requires 4 to 8 cwt. of kainit per acre. Chickweed (*Stellaria media*), nettles (*Urtica dioica*), lamb's quarters (*Chenopodium album*) and mustard (*Brassica arvensis*) are reported to have been killed by the use of kainit. Under similar conditions and for similar weeds calcium cyanamid has been used as a dry spray in America with some success. The nitrogen content of this material may have a stimulating effect on crop growth.

These dusts or dry sprays have never become very popular in America, probably for economic reasons.

#### ERADICATION OF PERENNIAL WEEDS

The eradication of perennial weeds by the use of chemical agents offers considerably more difficulty than does the destruction of annuals, and until recently no chemicals have been found very successful. The discovery of a rapid, efficient and economically sound chemical method of killing such weeds as field bindweed (*Convolvulus arvensis*), couch grass (*Agropyrum repens*), Canada thistle (*Cirsium arvensis*) and perennial sow thistle (*Sonchus arvensis*) on a field scale, would constitute an outstanding contribution to agriculture. The most encouraging step which has been taken towards this needed discovery is the results of experiments in the use of chlorates.

Åslander (9) has briefly reviewed the early work which has been done with potassium, sodium and ammonium chlorates and he has also contributed a very interesting piece of experimental work on the control of Canada thistle. He found that an application of 200 kgm. dry sodium chlorate (or 250 kgm. potassium chlorate) per hectare (approximately equivalent to the same number of pounds per acre) to the ground late in the autumn killed the roots of

Canada thistle during the winter. An application early in the spring was less effective. Chlorates penetrate the soil easily so that they reach the roots of the Canada thistle rapidly, and as they decompose comparatively slowly, they act efficiently. Moreover, these chemicals can be applied with little or no interference with the production of crops subsequently sown and they are found to have but slight influence on the biological activities in the soil. It has been suggested that if a weedy field is to be fall-ploughed an application of this herbicide in the furrows by some attachment to the plough would facilitate its action. Smaller amounts than those used in the experiment quoted might then be sufficient.

Latshaw and Zahnley (10) report that two applications of sodium chlorate solution (100 pounds to 100 gallons) killed 95 per cent of the field bindweed (*Convolvulus arvensis*) present in a badly infested area. They suggest that a third spray and possibly a fourth, would be needed to destroy this very dangerous and destructive weed. They observe that "the fundamental difference between the action of sodium chlorate and other chemicals used for weed destruction is that it not only kills the tops but seems to interfere with the manufacture of food in the leaves of the new growth. This new growth comes from the food stored in the roots. As a result the roots become exhausted and the entire plant dies."

The most favorable time for using sodium chlorate appears to be when the atmosphere is humid. While a slightly injurious effect upon plant growth may be observed on crops seeded very soon after applying, this is only temporary and no permanent injury has been observed. The cost of this chemical is about 6½ cents per pound f.o.b. Niagara Falls, or about \$20.00 per acre for three sprays of 100 pounds each to which must be added the cost of labour and machinery for applying.

Hansen (14) reports preliminary experiments in the eradication of couch grass with sodium chlorate. His results indicate that in the use of this chemical may be found a quick method of eradicating this perennial and widely distributed weed.

While the cost of sodium chlorate may prevent its adoption by farmers for general use on large areas, the good results so far obtained by its use against perennial weeds, lead one to believe that it will shortly fill an important place for killing weeds in small areas or patches.

The destructive action of chlorates is not clear as yet. Hansen states that examination has shown that the material penetrates the phloem tissue. It has been stated by H. K. Offord that the toxic action of sodium chlorate is due to the liberation of nascent oxygen under ultra-violet action of the sun.

#### ERADICATION OF LAWN WEEDS

Much work has been done in the control of crabgrass (*Digitaria Ischaemus*), dandelions (*Taraxacum officinale*), plantains (*Plantago*), chickweed (*Cerastium vulgatum*), moss, and other common lawn pests. It has been found that crabgrass requires moisture, heat and sunlight for its best growth, and by withholding water from the lawn during dry hot summer weather the growth of this weed will be greatly discouraged. The lawn

will not suffer due to the lack of moisture for at this period the grass will be in more or less resting condition.

In small numbers, broad-leaved plantain (*Plantago major*) may be killed by pouring a little crude carbolic acid or kerosene on the crown of the plant after first splitting it with a knife. Buckhorn (*Plantago lanceolata*) may be killed in a similar way.

For destroying sheep sorrel (*Rumex acetosella*), chickweed (*Cerastium vulgatum*) and lawn moss, a spray of 2 pounds of iron sulphate to a gallon of water, used several times during the summer, has been found effective.

Munn (11) reports experiments conducted at Geneva, N.Y., during a period of eight years in which dandelions were successfully eradicated from lawns with 4 to 5 sprayings with an iron sulphate solution with no material injury to the grass. It was found that the first spraying should be made in May just before the first blooming period. One or two others should follow at intervals of 3 or 4 weeks and finally one or two more in late summer or fall. Spraying during mid-summer injured the grass. The spray solution used was  $1\frac{1}{2}$  pounds of iron sulphate per gallon. The quantity of iron sulphate required for a single application was approximately 175 pounds per acre, or 4 pounds per 1000 square feet of lawn. The best results were secured when the solution was applied in the form of a fine mist-like spray well driven down among the foliage. Fairly satisfactory results were secured with a sprinkling can. To make the eradication of the dandelions complete it was found necessary to supplement the spraying operations with fertilization and reseeding.

Gilbert (12) has pointed out that by the application of ammonium sulphate to lawns the growth of practically all common lawn weeds has been discouraged and the growth of the red top, Rhode Island bent and fescue stimulated. Ammonium sulphate tends to make the soil acid in reaction but it has not been clearly shown whether it is the actual increase in acidity or the presence of large amounts of active alumina which discourages the weeds, or whether the nitrogen applied so encourages the growth of the grass that the weeds are actually crowded out. Where consistent use has been made of ammonium sulphate as a top dressing to bent grass lawns, the soils have become quite acid and weeds have practically disappeared. Gilbert suggests that a good fertilizer mixture to apply in the spring to every thousand feet of lawn might consist of 6 pounds each of ammonium sulphate, superphosphate and muriate of potash. Other workers have suggested an application of 5 pounds ammonium sulphate or ammonium phosphate per 1000 square feet several times during the spring and autumn months and 3 pounds to the same sized area during the summer. Ammonium sulphate or fertilizer mixtures are easier to apply if mixed with equal amounts of moist sand or other soil. As a top dressing for lawns some workers use screened top soil or compost to which is added the required amount of fertilizers. This top dressing will fill the hollow spaces in the lawn.

*The Gardener's Chronicle* of June 9, 1928, page 407, reports some experiments conducted at Stoke-Pogis, England, on two putting greens and a

large croquet lawn. Applications of ammonium sulphate of 5 pounds per 1000 square feet were made fortnightly between March 28 and October 29. A weed population of 50 per cent on the croquet lawn plots in March was reduced to 8 per cent by November. Untreated plots starting with a weed population of 37 per cent declined by November to 32 per cent.

There is some difference of opinion as to the weed control value of ammonium sulphate on lawns of Kentucky blue grass. Some workers claim that this chemical is as effective on this type of sod as on bent grass. Certainly for bent grass lawns no top-dressing appears to be so effective in the improvement of the grass and in the discouragement of weeds.

To get immediate action on broad-leaved weeds like dandelions and plantains, in particularly weedy parts of the lawn, Hansen suggests that ammonium sulphate should be mixed with 3 parts of sand and the combination dusted evenly over the weedy spots at 2 pounds per 100 square feet following dew or rain.

Vigor (16) has recently reported some observations on trials of iron sulphate, a crude sodium chlorate solution known as Atlas Non-poisonous Weed Killer and a white solid of unknown composition (Stoldt Weed Killer) upon Saskatchewan weeds such as mustard, stinkweed (*Thlaspi arvense*), perennial sow thistle (*Sonchus arvensis*) and Canada thistle.

While chemical agents have been used extensively and with considerable success in the eradication of annual and perennial weeds, such measures in themselves are often quite inadequate to cope with these persistent plants. Attention must also be given to such factors as drainage, soil cultivation, crop rotations, soil fertility and the use of seed free from weed seeds.

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## PRODUCTION PER MAN

J. E. LATTIMER †

*Macdonald College, P.Q.*

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For the past century generally and the past few years in particular, Canada has endeavored to increase the population by the expansion of farming method. Under such conditions it would appear logical and opportune to enquire into the man power requirements of this industry.

The numbers employed in the farming business depend upon two major factors. These are, first, the crops grown and the type or types of farming followed, and second, how these operations, whatever they may be, are carried on.

The crops grown and the types of farming followed are limited by the resources of the country and the markets available. The methods followed will be those which offer greatest prospect of reward.

The resources of soil, climate, topography, precipitation and distance from markets are naturally varied in a country the size of Canada. The stage of development is also varied. The development of some areas is so recent that the best authorities on the subject would hesitate to limit or define potential resources. Varied, however, as the resources of the country are known to be, there are very definite limits set to the choice of crops adaptable to the country. The limits are more narrowly restricted by the dependence on a distant market for the disposal of the surplus.

The agricultural resources of the country favour the production of farm staples which may be grown in a comparatively short growing season. There are exceptions to this in some sections of the older provinces and particularly in the province beyond the Rockies. The major portion of the country is adaptable to the cultivation of grasses and small grains. These crops are particularly adaptable to machine methods of production (1) and consequently labour requirement in their culture is not great.

Canada has always been a large importer of farm products. Recently, although she has become a large exporter of farm products, the importation continues. Imports of farm produce include specialized crops such as employ many people in their culture. Exports of farm produce are now expanding and continue to expand in the direction of crops adaptable to machine methods.

The labour utilized in farming is not great considering the extent of the country. Conditions in this respect vary from section to section and from time to time. It will be necessary to examine the development of the industry over a period of years. The number employed will also vary according to the method of organization and the way the business is carried on. These methods vary in different places and it may be interesting to compare our own with other lands.

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†Professor of Agricultural Economics.

The man power essential will vary with the technique with which the industry is carried on. Farming has been usually considered ill adapted to change. Recent movements have modified this view to a great degree. The changes in the technique of the industry made possible by scientific investigation, invention and education, have had and will have a great influence on the man power necessary in the business.

#### EMPLOYMENT BY INDUSTRIES

The allocation of labour force between different industries is a matter of recent rapid change and development. This is one of the most important phenomena of the times. To what degree this has taken place prior and up to 1921 may be noted from the following table (2):

TABLE 1. *Allocation of labour by industries (3).*

	1881	1891	1901	1911	1921
	%	%	%	%	%
Agriculture	48.1	45.8	40.2	34.3	32.8
Manufacturing	11.7	14.1	15.4	17.7	17.2
Trading and Merchandising	5.7	6.8	9.0	9.0	9.8
Building Trades	16.8	11.6	12.0	6.0	5.8
Transportation	2.9	4.3	4.5	8.0	8.5
Domestic and Personal	6.5	8.7	9.3	7.8	6.8
Professional	3.5	3.9	4.6	4.5	5.7
Civil and Municipal Government	0.6	1.1	1.0	2.8	3.0
Mining	0.5	1.0	1.6	2.3	1.6
Fishing and Hunting	2.1	1.9	1.5	1.3	0.9
Finance	—	—	—	1.4	1.9
Recreational	—	—	—	0.1	0.23
Unspecified	—	—	—	3.8	4.0

That excellent compendium of information, the Canada Year Book, to which we shall have frequent reference, explains this table briefly. It notes that the providers of time, place and possession utilities have increased proportionately in recent years, while the providers of form utilities such as farmers and manufacturers have failed to hold their own proportionately.

Transportation, or the providing of place utility, saves effort in farming by enabling land and labour both to be devoted to their greatest adaptability. This factor has been important in reducing the man power necessary to secure desired results in farming as we shall later see.

The major factor for our consideration in this table is the regular and fairly rapid decline in the proportion of the gainfully employed who are engaged in agriculture during this forty year period.

There are numerous factors contributing to this result which we may not discuss in detail at this point. They include the movement to urban centres of many who formerly lived *on* the farm but not *by* farming and also the improved methods and machinery available for carrying on the work of farming. These matters will be discussed more fully after we have considered other records.

The trend towards urbanization is frequently deplored. We are at present interested only in exposition. After this has been concluded we shall refer again to the criticism of this trend towards urbanization.

## NUMBER EMPLOYED IN FARMING

We now consider the number of workers engaged in agriculture. Specific figures for the past four decades are available. They are recorded in table 2 (2):

TABLE 2. *Workers engaged in agriculture*

1881	662,266
1891	735,207
1901	716,860
1911	933,735
1921	1,041,618 (3)

A record for a longer period of years would be interesting. Comparable figures are, however, not available as 1881 was the first census of the Dominion including more than four provinces.

These figures are very surprising. It is something of a revelation that the total number of workers in agriculture in 1921 only slightly exceeded a million. Nothing could be more surprising, except perhaps the slowness of the increase in the number employed in this industry. In forty years the number employed has nowhere near doubled. Yet during that time the industry has developed quite a reputation as a contributor to the export market.

During one decade, that between 1891 and 1901, the number employed in agriculture actually decreased. During this time, however, the area cultivated increased. If any explanation is required as to the reason why the number employed in farming decreased during the last decade of the past century it may be found in the prices of farm products of that time. These prices were partly due to a world-wide depression. They have also been attributed by one historian to the general use of the grain binder which was blamed for the "collapse" of land values during this period when wheat was fed on nearly every farm in the county described (4).

During the first decade of the present century the number employed in agriculture increased materially. This was the period of rapid settlement of the western provinces. These provinces were to a certain extent available at an earlier date as the first transcontinental railway was completed in 1885, but the record reveals that employment in the industry does not increase if and when prices of farm products are such that profits are hopeless.

The pronounced feature of these figures is the smallness of the number employed in the industry when compared with results obtained. Explanation of this requires at least a brief glance at the development of the industry. It is now almost exactly three centuries since Louis Hébert, the first farmer in what is now Canada, was granted the first seigniority. The evolution of Canadian farms since that time into what they are today is an interesting story which may not be discussed here. Yet in that evolution many types of farm organization and land tenure were tried out and discarded. The form of tenure and organization which today prevails has been largely a result of the trial and error method. It is no general criticism that the evolution of farms as they today exist has been similar in this respect to the development of the British Constitution.

The question is, what have these farms developed into in this period? They are today among the outstanding examples of the owner operated farm

(5). Further, they are owned by operators who furnish a large proportion of their own labour requirements. In other words there exists no permanent class of farm labourers in this country.

This was not always the case to as great an extent as at present. Before farm machinery was as important a factor as it now is, there was a time when the workers in agriculture were classified into three classes in this country, namely, owners, tenants, and labourers. In 1881 that classification existed in the census report. The succeeding censuses dropped this classification of labourers in the rural areas.

The census of 1921 enumerated 711,090 farms and 1,041,618 workers in agriculture. The great majority of the owner-operators supply the major portion of their own labour force. The balance is supplied by other members of the farm family, farmers' sons, prospective farmers serving their apprenticeship and transient labourers.

Allowing one working manager for each farm, which is the usual condition, these records show that not one half the number of farms in operation employ one hired worker continuously. The labour available for hire is largely made up of those seeking experience in the business. A popular method of procedure to farm ownership in this country is the acquiring of experience and some cash as a farm wage earner.

Expenditure for hired labour in Canada during the last census year, including allowance for board, amounted to an average per farm of \$185.17. This varied by provinces as shown in table 3 (6):

TABLE 3. *Expenditure for hired farm labour by provinces.*

Canada	\$185.17
Prince Edward Island	62.62
Nova Scotia	56.98
New Brunswick	65.53
Quebec	84.77
Ontario	166.66
Manitoba	332.81
Saskatchewan	301.20
Alberta	260.52
British Columbia	259.25

The transient as well as other labour hired in farming amounts to a certain degree to the employing, by those who operate larger areas, of those who are unable to employ themselves profitably although also classed as farmers. The industry to a great degree applies its own labour force. The chief exception to this is the prospective farmers who are gaining experience with the purpose of eventually becoming farmers.

Any enquiry into the nature and causes of the accomplishments of Canadian agriculture must arrive at the deduction that it is largely due to the abundant supply of land. The chief cost of land in this country is now and has always been the trouble of improving it.

This difficulty was pronounced while the older provinces were being settled. The result was that much labour was employed in proportion to results reckoned in farm produce. Tenure problems, lack of machinery and lack of transportation combined to prevent farming in anything like an extensive way. The area of land which one family could or wished to improve amounted to only a few acres.

Compared with improving or reclaiming an eastern farm from virgin forest the so-called pioneering of the newer western provinces is quite a simple matter. It does not extend over such a long period of time. This is the explanation of the fact that over half of the acreage devoted to farm products in Canada is in the two provinces of Saskatchewan and Alberta which provinces were only formed in 1905, although there were a few settlers located in the district prior to that time.

Land is much more easily and rapidly acquired during the twentieth century than during the previous two as far as Canada is concerned. The plentitude of land is one of the reasons for the scarcity of labour in the farming industry. It is at the same time the reason for the remarkable accomplishments of the industry in the aggregate.

How has this come about? The labour available in the industry is supplied by those who intend to farm for themselves. Land is to be had for the reclaiming. Why be a wage earner under such conditions? Confronted with free or cheap land, with almost no man labour available for hire, what was the temptation? Machines to work more land.

The advent of the grain binder perfected only fifty-two years ago marked an epoch in reducing the number employed in farming. This corresponds with the record of employment fairly closely. The grain binder is credited with revolutionizing farming and giving the world cheap bread (1). The general use of the grain binder released an army of day labourers from the rural villages who were formerly pressed into the service to help raking and binding and otherwise meet the peak load of labour requirements which was the garnering of the harvest. This displaced labour has been reinstated to some degree in making the machines. In this way they may find more regular employment, for making machines need not be as seasonal as harvest operations.

This invention by looking after the peak load in labour requirements promoted the invention of other farm machinery and stepped up efficiency all along the line. The result was that larger acreages could be cultivated by one operator than was before conceivable. This result was reflected in the later settlement of the west and even in the more recently settled portion of Ontario and Quebec in larger allotments of land. These larger original grants, and on the prairie the ease and rapidity with which they were brought into cultivation, extended man power over more acres. It has been claimed that the farmer of Saskatchewan who does not grow at least one hundred acres of wheat has small hope of reasonable reward for his effort (7).

But the grain binder today is being rapidly superseded. It served its purpose well in its age and generation. If the grain binder revolutionized agriculture, then the combine reaper thresher promises another revolution in this industry, a revolution of a similar nature and of wider influence.

The grain binder at its best reaped a swath from 5 to 8 feet in width, binding it into sheaves at the same time. A real expert cradler could and did lay low a swath 8 feet wide. In a day a binder covers from 8 to 16 acres according to the width and speed applied, while with a cradle one man has "downed" as much as four acres in a day. The value of the grain binder was

remarkable in the alleviation of drudgery. In increasing the acreage operated per man it was not as important as more recent inventions.

The combine is in quite a different class in this respect. It enables one man to replace many and at the same time eliminates drudgery and may reap and thresh in one day from 30 to 50 acres. By the replacing of man by machine power the combine has also stepped up efficiency all along the line.

The possibility of two or three men (allowing one to haul the grain away) reaping and threshing 50 acres in a day has removed the peak load of farm labour from the harvest time. This has made possible and necessary the use of larger tractors, larger plows, wider cultivating and seeding machinery, and motor trucks to haul the grain to the elevator. It is now possible to seed, harvest and thresh an acre of wheat with less than two hours of man labour (8).

There can be no other result from the increase in the use of this device than the material reduction of employment in the farming industry. Fewer farm workers will be able to produce more. This is what has been happening on this continent for a considerable time (9). This movement has been pronounced during the past twenty-five years, more noticeable during the last fifteen and has been accelerated during the post war period. That it is in response to necessity will become clear as we proceed.

#### FEWER WORKERS PRODUCING MORE

One of the most striking developments in the farming industry during the first two decades of the present century has been the great increase in production of farm products with a comparatively small addition to the labour force. The increase in number employed, acres cultivated and results achieved, may be considered for that period. The percentage increase in the two decades is given in table 4.

TABLE 4. *Percentage increase 1901-1921.\**

Surplus of agricultural exports over imports by value	600%
Acres cropped	141 "
Acres improved	135 "
Acres occupied in farms	122 "
Number employed	.45 "
Number of farms	35 "

These figures indicate that the rate of increase in farm products is altogether out of proportion to the number employed in the industry. Production is only approximate and is given by value as this is the most accurate estimate obtainable. Naturally the difference in the general price level must be considered as influencing the value figure. But in 1921 the prices of farm products were not very much over the 1901 figure as the post war deflation had taken place to a certain degree by the year 1921 when the farm price of wheat was 81 cents per bushel (10).

During the twenty year period the area devoted to wheat became five times as great, the export of wheat thirteen times as great in quantity and the export of flour almost six times as great in quantity. The value of dairy products was multiplied by three during the period.

The expansion of farming has been during this century largely in the direction of growing wheat. This is simply an endeavor to equate natural

\*Data from Dominion Bureau of Statistics.

resources with world market demands. This type of farming by methods which are now being used and becoming ever more popular requires no great amount of man power in the farming industry.

#### EXPANSION OF GRAIN GROWING

Why is the expansion of farming taking this direction? It is true that western Canada enjoys a comparative advantage in growing wheat over other exporting countries, both in quality and yield per acre (5). Oats and potatoes are even more generally adaptable to Canadian conditions. The oat grain is not in great demand unless turned into more acceptable products such as butter, beef or bacon. Potatoes are too bulky to be shipped around the world. In 1871 the wheat acreage amounted to 1,646,781 acres while the potato acreage was some 400,000 acres. Last year over 24 million acres were devoted to wheat while the potato acreage was nearly 600,000 acres. Hence while the wheat area has been expanded by fifteen times, the potato acreage becomes only one half larger. If anyone imagines that the potato acreage is not increasing fast enough let them consider the price of potatoes of the past year or consult the potato grower. Growing potatoes requires more man power per acre than growing wheat. This line of farming can only be expanded on the basis of a market which is not far away.

The man labour required in farming depends very largely on the variety of crops grown. During recent years the area devoted to fruit growing, vegetable growing and potato growing has actually contracted. The aggregate production has not, however, decreased. This is partly due to improved methods and partly to the increased specialization which has enabled both grower and section to follow the line of greatest adaptability. The lack of expansion may also be attributed to the increasing imports of fruit and vegetables not particularly adaptable to this country. The imports of vegetable products into this country for the calendar year 1928 amounted to some \$236,000,000 in value (11).

Expanding our farming in the direction of growing more wheat and importing a greater proportion of fruits and vegetables may perhaps increase the revenue of farmers but it will not require many workers in the farming industry. This is on account of machine methods being more applicable to wheat growing than some other lines of farming.

#### ACRES CROPPED PER MAN

The opening up of the western prairie country, the easily cleared park lands of the newer provinces and the expansion of farming in the direction of wheat growing, are factors which have all combined to increase the acres cropped per man during the past few decades. Progress in this respect may be studied from chart 1.

These figures are very instructive. It may be noted that the forty years recorded here reveal two methods of carrying on this business. During the first decade of this record the acres cropped per man actually decreased. That was prior to the availability of western land and before farm machinery was much in evidence. The last decade of the 19th century started the movement in the other direction. Farm machinery became more generally used

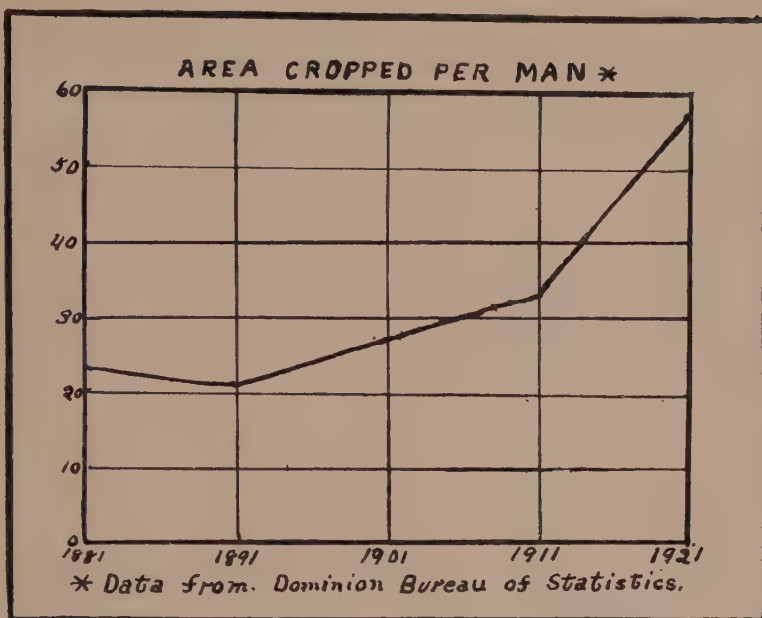


Chart 1.

during this period. The first decade of the present century recorded many workers added to the industry and many new western farms added. During this decade the area cultivated per worker was not increased rapidly. During the second decade of this century fewer new farms were added and the number of workers increased less rapidly but the acres cultivated per man increased by 75 per cent, from 32.7 acres in 1911 to 57.3 acres ten years later.

This was a decade when men were scarce, farm products in demand and machinery more generally resorted to. The area cultivated per man varies from section to section as well as from time to time. The variation existing by provinces in 1921 is shown in chart 2.

The area cropped per man is several times greater in the prairie provinces generally than in British Columbia and Nova Scotia. This is owing partly to the different types of farming carried on. It is also partly due to the more general application of machinery in the grain growing areas.

A similar explanation is needed to account for the fact that the area cropped per man is almost three times as great in the prairie provinces as in Ontario and Quebec. Yet some further explanation appears necessary. It is generally claimed that western methods are extensive while those of the older eastern provinces are intensive. This claim needs serious modification.

Of the approximately sixty million acres of crops grown in Canada annually, wheat accounts for about 25 million acres, oats 13 and hay 10 million acres. The area devoted to oats and hay is fairly constant while recent expansion has been in the direction of increasing the wheat area. The oat crop is common to all the provinces, wheat is confined largely to the three prairie provinces while the older eastern section is the hay area.

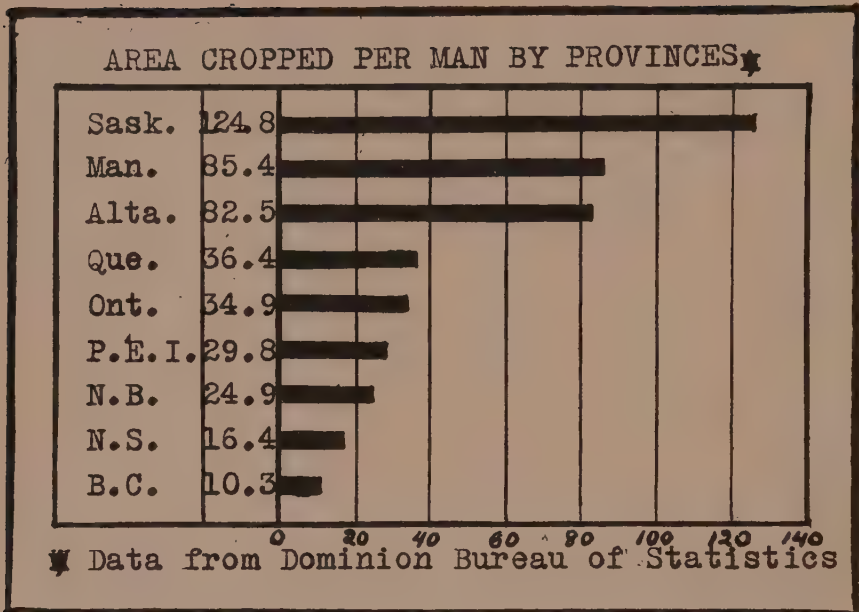


Chart 2.

In the provinces of Nova Scotia, New Brunswick and Quebec some sixty per cent or more of the area in field crops is devoted to hay. No criticism is advanced here of this allocation of crops. The proportion happens to be about the same in England. What is maintained is that the growing of hay is by no means intensive cultivation. This is particularly true where the hay grown is largely from permanent meadow.

However applicable to local conditions this type of farming may be it will not require many labourers. If and when it does endeavor to employ much of a force of man power, wages will be low as the industry will be overmanned. This condition has been reported in England (12).

When all allowance is made for differences in adaptability of soil and climate as between the eastern provinces and the prairie section the main factors influencing the acres cultivated per worker in the two regions are the stage of development and the distance from markets. The newer areas were organized on a more extensive scale on account both of the date of settlement and the ease of bringing the land under cultivation. Organized for the production of a product in world demand on a distant market the only possibility of profit was in farming extensively. This necessity was clearly set forth by Von Theunen over a century ago (13).

#### EFFICIENCY AND PROSPERITY

There is a tendency to employ less labour and more machinery to land during recent years. The reason is clear. We use sparingly that factor which is the most expensive. Land is now one of the few things—and there are a few such as motor cars, gasoline, rubber and sugar—which is no more expensive in dollars than in 1914. And the dollars are worth less. Capital

is about as easy to obtain as in 1914 as the interest rate is not much different. Farm wages, however, are about twice as high as in 1914, the figures being \$323 per year in 1914 and \$634 for the year 1928 (14).

Under such conditions increased profits may only be obtained by making man power more efficient with more knowledge and more capital so that more land may be operated.

This method may make possible the extension to farming, to a certain degree and within certain limits, of an accomplishment which has been demonstrated in a large way in some industries during this century. This is the possibility of having at one and the same time lower prices for the product, rising wages in the industry and profits. This is being achieved in farming as in other industries by fewer workers producing more. This increase in efficiency requires fewer workers in the industry.

#### MECHANIZED FARMING AND FOOD SUPPLY

The degree of cultural attainment possible to any individual or any group depends upon, and is in inverse ratio to, the proportion of effort expended on securing the necessities of life.

For centuries the chief end and aim of mankind in general has been to secure food. True in Athens during its immortal days the free men of that day did not demean themselves with such mundane matters. But the free men of that period comprised only a small proportion of the population. It was somewhat similar at the time of imperial Rome. And yet a recent book which modestly claims to be the first economic history of that empire claims that about 80 per cent of the effort of the married labouring man was necessary to secure food (15).

Slowly but successfully, struggling against public opinion and parliamentary statutes, a more indirect method of providing food has in some small sections of the world made its appearance. Today we find that the Bureau of Economic Research at Washington places the expenditure of the American family as follows (16):

All purposes	100%
Food	38.2
Clothing	16.6
Housing	13.4
Fuel & Light	5.3
House furnishing	5.1
Miscellaneous	21.3

This result in the United States is of fairly recent date. It is reported that in 1870 out of every 100 workers 47 were employed producing the prime necessities while 53 were released for other effort. In 1920 only 26 out of 100 were required to produce the prime necessities, leaving the other 74 available for other work (1).

In 1820 in the United States 73 per cent of those gainfully employed were engaged in agriculture. In 1920 only 26.2 per cent were so engaged (17). Still, judging by reports, the surplus of farm products is more troublesome since 1920 than it was one hundred years ago.

Farm labour became 18 per cent more efficient in the United States during the decade 1910-20. Farm workers decreased over 4 per cent during

that decade while there was a 13 per cent increase in the mass of crop production.

In Canada it is impossible to secure figures covering such a long period. Those of the present century are, however, of special interest. The bureau of Statistics presents the following estimated expenditure of the weekly Canadian family budget (18):

	1900	1928
Foods	\$5.48	\$10.80
Fuel & Light	1.50	3.29
Rent	2.37	6.91
Proportion of food to total	59.1%	51.7%

For the past quarter of a century the securing of food has exacted a decreasing proportion of the expenditure of effort. This is just what common sense would expect and logic dictate. Yet this very point is frequently and repeatedly challenged.

How may food be secured with the expenditure of a decreasing proportion of effort and the growers of food be prosperous as well? The answer is clear if we allow facts some influence. It is by increasing efficiency by improved methods and more equipment. Slavery did not secure cheap food nor did serfdom go far in this direction. Neither can peasant farming claim to have achieved much in this line (19). The mechanized farming of this continent and Australasia has already proceeded much farther in this direction than did the man with the hoe. And recent developments are only beginning to proclaim future possibilities along this line.

This development, however, removes workers fairly rapidly from the farming industry. On this account it is fairly generally deplored. The good old days are often lamented. The departure of the "pioneering spirit", whatever that may be, is a subject of journalistic comment.

If less than half of the expenditure of the family budget is for food, then it must necessarily follow that more than half the population cannot afford to expend their effort catering to this demand. If more than are needed engage in this work returns are apt to be low and the standard of living of those in the business low as well.

It may be argued that this only applies to farmers on a domestic market. Granted. The farming industry in this country is on a world market for wheat to the extent of about 75 per cent of the total production. Other farm exports consist chiefly of dairy products, beef and bacon. Exports of dairy products and beef represent about 15 per cent of total production and are declining. Bacon exports vary greatly and in this particular line the way to secure a favourable price on the world market is for a dozen countries to limit supplies, as is being done in the present season.

If world demand is considered then world supply also enters the equation. Canada last season produced a surplus of wheat for export equal to about 50 per cent of the world's present import requirements at present prices. It has been repeatedly pointed out that production could be doubled. Continuation of the rate of increase maintained during the present century would find production doubled in about thirty years, or by 1960. Con-

tinuation of the rate of increase since 1911—during a period when the number employed in farming did not increase materially—would double production in about 22 years, or by 1950.

It is unnecessary to speculate upon this development. World demand and supply and world competition will settle this question. The point that is maintained here is that this development, should it take place, will not employ many in the business of farming. This is patent from the trend of the past few seasons, particularly in the wheat growing areas. This argument is supported by the number of transient labourers required recently for the western harvest. The same issue of the *Montreal Gazette* which published the estimated transient labour requirements for the 1927 harvest, which was 25,000, in its column relating incidents of 25 years ago presented exactly the same estimate, 25,000. How great the expansion has been in production of wheat during that period is well known. This substantiates the argument that the increase in production of wheat is quite out of comparison with the number employed in the growing of the crop. The number of transient labourers moved by the Canadian Pacific Railway from eastern Canada to the western harvest fields during the past few years also supports this claim. These numbers were—

1923 .....	20,600	(20)
1924 .....	10,994	
1925 .....	25,398	
1926 .....	12,888	
1927 .....	12,195	
1928 .....	17,363	

The grain growers have invested in the past three years some \$12,000,000 in combine harvesters (21). A continuation of this movement, now in its infancy, must result in less dependence on transient labour for the western harvest.

There is another possibility, which is that too many growing food may make food as dear as it has been in the past and as it is today in some parts of the world.

A recent survey points out that in an area in China where freight rates do not oppress as there are no railways, and middlemen do not exact too great a toll as farmers do their own marketing, the fight against starvation is so severe that a greater amount is spent on fertilizer than on education. Scientific agriculture is unknown in that region (22).

Another report from India records that in a village where all are farmers except the storekeeper, who is also the money lender, the only products purchased are cloth and salt and in the Arcadian simplicity there prevailing 97 to 98 per cent of the total expenditure is necessary to secure the absolute necessities of life.

The obvious method to make food expensive is to have all or nearly all the workers farming. This is apparent from past history as well as from a comparison of different parts of the world at the present time. The method of securing food easily is to combine a little labour with much waiting rather than combine labour with less waiting, as Marshall puts it (23). In other

words use more machinery and more efficient methods. The increasing tendency to do this in Canada and particularly in wheat growing explains why about one million workers in the farming business have been able to grow upwards of half of the world's import requirements of this commodity.

Perhaps this increasing tendency may also explain—if any explanation be needed—why Canada has recently been unable to increase her population materially by the expansion of farming method.

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#### BOOK REVIEW

LABORATORY AND FIELD ECOLOGY. *The Responses of Animals as Indicators of Correct Working Methods*—By Victor E. Shelford. (The Williams & Wilkins Co., Baltimore, 1929, Pp. xii + 608, fig. 219. Price \$10.00).

In this volume, Shelford has made a noteworthy contribution to animal ecology. This contribution lies primarily in the viewpoint, selection of material and direction of emphasis.

In contrast to previous recent books in this field, the emphasis here is (1) upon the study of communities, determined by predominant organisms, as the essential basis of ecology; (2) upon continuous field observation, quantitative and other, as the primary method for such study; and (3) upon climate-simulation in the supplementary experiments, which should relate above all to the predominants. "It is the purpose of this book to outline the

equipment and methods which conform to present knowledge of the responses of animal organisms in general." "To a large extent, in fact, the organism itself dictates the character of the apparatus to be used. This idea is the main thesis of the present volume . . . ."

In the working out of this original objective, more than half the book is devoted to presentation and discussion of ecological data. In general, the subject matter seems referable to four major purposes or ideas:—(a) To define the viewpoint and suggest the problems of ecology. This discussion, obviously the outgrowth of long experience touching every phase of the work, is of general scientific interest. It is of special value to any type of ecologist. (b) To discuss environmental factors, singly and in combination. This presentation seems not exceptional, save as it relates to the main thesis and the discussion of light effects. A distinct contribution is in the emphasis upon multiplicity of factors and the essentially complicated nature of responses. (c) To describe principles and methods of field and laboratory study. That portion, particularly, which deals with biotic observation is by far the best available discussion of this subject. It brings together from scattered sources and the author's wide experience, a well-rounded suggestive outline of procedure. (d) To detail, in principle and practice, equipment for measuring and controlling environmental factors. This section should be of much value in the selection and use of items or ensembles of biological equipment, especially in view of the author's close familiarity with much of the apparatus mentioned. It seems unfortunate that several comments of general interest are hidden amongst a mass of technical detail.

The extensive bibliography has been freely, but in the main judiciously, referred to. The author's careful re-presentation, in many instances, of others' data, and their critical examination generally, serve to increase the usefulness of the book.

The work is not without imperfections, which for the most part are frankly recognized by the author. In a field still very incompletely organized, where many of the data and ideas are very new, it is not surprising that the presentation is not always well balanced. The difference in clarity and value of treatment is often marked, as between the more recent and the somewhat older concepts. There is perhaps too great space allotted to not well established theories, and to material local to the author. It seems a valid criticism, as made to the reviewer by several competent observers, that the book is somewhat hard to read; the great concentration of much of the writing, and the fact that the author seems to have written primarily for the specialist, doubtless have much to do with this.

These defects, however, are not serious nor do they detract greatly from the value of the general contribution. This volume, then, will prove of much interest to the general scientific reader. It will serve as a valuable reference work in many biological courses. It will be of much assistance to those using equipment of this type. Finally, it is indispensable to anyone interested in the field of ecology.

K.M.K.

# LE PROBLEME HORTICOLE DANS LA PROVINCE DE QUEBEC

J. H. LAVOIE

*Chef du Service d'Horticulture, Ministère de l'agriculture de Québec*  
(suite)

Ainsi, depuis le 1er avril 1927, à venir au 20 février, 1929 il est entré sur les marchés de Montréal et Québec seulement, 10,993 wagons de produits arboricoles et maraîchers, dont 5,678 wagons venaient des autres provinces et 5,315, des Etats-Unis. Il est important de noter ici que ces chiffres ne comprennent pas les produits de même nature qui nous sont venus de l'extérieur, pendant la même période, autrement que par wagons complets, soit par mer ou par terre, par fret ou par messagerie, ou qui pouvaient être à destination de villes autres que Montréal et Québec.

Ils ne sauraient non plus inclure toutes les quantités de fruits exotiques que nous avons importés, pendant ce temps, puisque du 1er avril au 30 novembre 1928 seulement la ville de Montréal a reçu 6,527 wagons de fruits frais et 924 wagons de bananes.

Pour ne pas donner raison à ceux qui voudraient infirmer l'éloquence de ces chiffres, en objectant qu'il s'agit surtout, en l'occurrence, de produits de primeurs ou exotiques, nous allons en donner ci-contre l'intéressant détail, à savoir: pommes: 1929 wagons; cerises: 2; prunes: 109; framboises: 4; fraises: 209; choux: 246; oignons: 381; tomates: 1291; céleri: 465; concombres: 214; laitue: 314; choux-fleurs: 81; épinards: 115; asperges: 14; pois verts: 24; carottes: 98; haricots verts: 46; pommes de terre: 4039; légumes mélangés: 458; fruits mélangés: 664; légumes et fruits mélangés: 290.

Un simple coup d'oeil sur ce tableau suffit pour convaincre le moins averti des horticulteurs que les quatre-cinquièmes de ces importations ne sont justifiés que par l'impuissance dans laquelle se trouve présentement l'horticulture québécoise de répondre aux exigences de la demande, au point de vue qualitatif. Nos importations seraient considérablement diminuées si l'on s'était avisé de faire l'éducation du consommateur de pair avec celle du producteur. Lui serait-il indifférent, par exemple, de consommer des choux de primeurs importés à raison de \$4.50 le baril, prix de gros, s'il savait que nos choux d'hiver, infiniment plus savoureux, ne se vendent que de \$1.50 à \$2.00? Et cependant, il en a consommé le contenu de 246 wagons, à ce prix!

Mais ce sur quoi il faut insister davantage, c'est sur les quantités exorbitantes de pommes de terre que nous avons reçues de l'extérieur, parce qu'elles prouvent, mieux que toutes autres, combien j'ai raison de dire que ce n'est pas tant la quantité que la qualité qui manque à nos productions pour répondre aux exigences de la demande. Personne n'ignore que notre province est la plus grande productrice de pommes de terre qui soit au Canada, et que sa production annuelle de tubercules excède de plus d'un million de boisseaux celle des Provinces Maritimes réunies.

Or, du 1er septembre 1928 au 20 février 1929, nous avons reçu d'elles 1894 wagons de tubercules, cependant qu'il en reste au delà de 4,000 wagons des nôtres qui sont encore à vendre, à l'est de Québec. Notre production

de tubercules n'étant pas uniformisée et classifiée, et la leur l'étant; notre moyenne de production n'étant que de 140 boisseaux l'acre, alors que la leur est de 250, et les taux de transport étant à peu près les mêmes dans les deux cas, il s'ensuit qu'elles ont l'avantage sur nos propres marchés. Et dire que cette production est l'une de nos plus importantes: ainsi en est-il malheureusement pour les autres. C'est ce qui explique pourquoi nous avons reçu de l'extérieur près de 11,000 wagons de produits horticoles et arboricoles provenant d'une vingtaine d'espèces tout au plus, dans l'espace de 702 jours, soit 15 wagons, en moyenne, par jour. Quand on sait que les cinq places de marché de la ville de Montréal ne reçoivent annuellement que 600,000 voyages de produits horticoles et arboricoles, on est justifiable de s'inquiéter sur l'avenir de l'horticulture québécoise.

Voilà pour ce qui regarde les quantités de produits qui nous viennent de l'extérieur à l'état frais. Mais ce n'est pas tout. A celles-là, il faut ajouter celles des produits secs et manufacturés qui ne sont pas moins déconcertants.

Ainsi, du 1er avril 1926 au 31 mars 1927, il s'est importé dans la province de Québec:

296,634	mts de haricots secs, d'une valeur de	\$536,053.00
649,014	lbs. de tomates en cons. " " "	47,316.00
85,164	" " maïs sucré " " "	6,856.00
383,699	" d'asperges en cons. " " "	53,736.00
153,143	" de haricots au lard " " "	8,448.00
1,510,865	" " pois verts en cons. " " "	103,852.00
1,062,873	" " houblon " " "	309,893.00
20,355	" " graines de sem. " " "	72,755.00
15,476,536	" " tabac " " "	5,267,613.00
	fleurs coupées " " "	29,332.00

Vraiment, il y a là matière à faire réfléchir sérieusement ceux qui ont à coeur de protéger les intérêts de la province et d'en assurer l'avenir économique. Somme toute, si l'agriculture ne paie pas, chez nous, ce n'est sûrement pas parce que nous manquons de marchés. Ainsi c'est chose reconnue et admise par les manufacturiers de conserves et d'accessoires pour leur fabrication que le marché de Montréal absorbe trois fois plus de conserves de tomates et deux fois plus de conserves de pois verts et de maïs sucré que celui de Toronto. Et pourtant, ce n'est pas dans la province de Québec, mais bien dans celles d'Ontario et de Colombie-Britannique, qu'il s'en fabrique davantage, comme l'attestent les statistiques fédérales. Elles nous apprennent, en effet, qu'il existait au Canada, en 1926, 272 fabriques, dont 178 se trouvaient dans l'Ontario, 34 dans la Colombie-Britannique, et 33 dans Québec; que la valeur totale de leur production était de \$16,233,960, celle de l'Ontario étant de \$11,302,579, celle de la Colombie-Britannique, de \$3,430,555, et celle de Québec, \$1,371,962; que le montant des salaires payés par ces industries s'élevait à \$2,111,724, dont \$1,384,967, dans l'Ontario, \$582,435, dans la Colombie-Britannique et \$110,866, dans Québec.

Toute considérable qu'elle puisse apparaître, cette production manufacturée est encore loin de répondre aux besoins des consommateurs canadiens, puisque d'après la même source d'information, le Canada dut importer, durant cette année-là, les quantités suivantes de conserves alimentaires:

Articles	Quantité (lbs.)	Valeur (\$)
Pommes de terre desséchées :		22,968
Haricots au lard :	2,064,985	125,923
Maïs sucré :	1,477,019	100,303
Pois verts :	3,098,110	226,497
Tomates :	1,036,163	77,695
Légumes divers :	4,879,259	517,540
Asperges :	844,681	125,370
Marinades :	96,318 gals.	130,083
Total :	13,400,217	1,326,379

Bien que le marché intérieur soit le débouché le plus important, le marché extérieur, malgré son instabilité, constitue parfois un excellent débouché pour l'écoulement des produits d'un pays qui possède, comme le nôtre, des avantages naturels et économiques tout à fait exceptionnels. Ainsi, favorisée comme elle l'est, non seulement par l'aptitude culturale de son sol et de son climat, mais encore par sa situation géographique, par l'abondance de sa main-d'oeuvre, par la valeur relativement peu élevée de sa capitalisation foncière, la province de Québec se trouve beaucoup mieux située que celles d'Ontario et de Colombie-Britannique pour faire de l'exportation. Cependant, le défaut de qualité de ses productions fruitières fait que c'est elle qui exporte le moins, comme le prouvent les statistiques fédérales suivantes, pour l'exercice fiscal 1926-27 :

Articles	CANADA		QUEBEC	
	Quantité totale exportée	Val. totale	Quantité	Valeur
Pommes :	1,038,768 bls.	\$4,670,091	200 caisses	pr. exp.
Pommes de terre :	8,319,080 mts.	9,717,425	325,131	\$409,043
Choux-navets :	2,049,849 "	665,272	299,684	93,245
Oignons :	84,399 "	125,439	20	33
Fraises :	318,406 lbs.	47,715	1,321	238
Tabac :	6,330,972 "	.....	150,000	.....

Si l'agriculture ne paie pas, chez nous, ce n'est sûrement pas, non plus, parce que nous manquons de débouchés, comme on peut le voir.

Pour être complet, il faudrait parler de nos productions spéciales, telles que tabac, chicorée à café, houblon; de nos industries pépiniéristes; de nos cultures forcées; du lamentable état de stagnation de notre culture ornementale et de l'organisation officielle et privée de l'horticulture. La place ne le permet pas.

On ne saurait toutefois fermer ce chapitre sans appuyer sur le fait qu'en dépit de l'éparpillement de ses cultures et du manque de coopération de ses producteurs, l'horticulture québécoise est encore présentement l'une des branches les plus payantes de l'industrie agricole. Et ce fait est à tel point reconnu que, de toutes parts, les agriculteurs y recourent en masse—comme jadis les assoiffés d'eau lustrale—pour en obtenir les profits que la culture extensive est impuissante à leur procurer. Aussi est-elle devenue la production auxiliaire indispensable à tout cultivateur qui veut développer sur sa ferme un système d'exploitation rationnelle capable de le faire vivre et de lui assurer des profits.

Au reste, les moyennes de profits nets de \$252.00 par arpent, pour la culture maraîchère; de \$342.00, par arpent, pour celle des petits fruits, et de \$283.00 par arpent, pour celle des pommes, que nous avons obtenues, depuis trois ans, dans nos champs et vergers de démonstration, doivent suffire à justifier nos avancés.

Puisque le progrès de l'agriculture est si intimement lié au développement de l'horticulture; puisque les facteurs écologiques et économiques sont si favorables à ce développement; puisqu'enfin, la "manie de la laideur" est en train de défigurer "le visage aimé de la patrie," il est temps ou jamais de donner à l'horticulture québécoise l'essor qui, la dégagant de ses liens, lui permettra de semer à pleines mains sur le pays la richesse nécessaire à l'amélioration des conditions matérielles et les luxuriantes végétations indispensables à l'adoucissement des conditions morales d'existence de l'homme des champs.

## II.—*Ce qu'elle devrait être.*

L'horticulture québécoise ne prendra cet essor vers la prospérité que si ses cultures fruitières, maraîchères et spéciales reçoivent une impulsion commerciale et industrielle capable de leur faire dominer la concurrence, et que si ses cultures ornementales reçoivent un élan assez fort pour les dégager de l'ornière de la routine, et une direction qui puisse les conduire vers les sommets de l'art esthétique.

L'obtention de ces résultats ne sera toutefois rendue possible que par l'éducation des différentes classes de la société, que par l'intelligente coopération du technicien, du producteur et du consommateur, et que par l'intervention des pouvoirs publics dont le rôle est d'éduquer les masses, d'aider au développement des forces productrices et au maintien de leur équilibre.

Faire l'éducation horticole du producteur, c'est-à-dire le renseigner sur les exigences de l'offre et sur les moyens d'y satisfaire; lui ouvrir des horizons nouveaux sur les développements en perspective de son industrie; lui faire acquérir des habitudes de commerce, d'honnêteté et d'économie; développer chez lui le goût des belles végétations et le sens artistique: voilà la clef de voûte du problème horticole, puisque c'est d'elle que dépend sa solution.

En effet, aussi longtemps que le remueur du sol ne s'appliquera pas à produire un article dont la qualité soit en tout point conforme aux exigences de la demande; tant qu'il ne sera pas convaincu de la nécessité d'y satisfaire, d'augmenter ses rendements et d'abaisser son coût de revient, pour rendre son industrie payante; tant qu'il ignorera tout de l'organisation commerciale et industrielle de la production, telle qu'elle est chez nous et chez concurrents; qu'il continuera, par une habitude invétérée, à dissimuler des rebuts à travers une production de belle apparence et que toutes ses économies iront à la ville au lieu de retourner à la terre; aussi longtemps que les abords de son logis seront dépourvus de cette décoration végétale et florale qui en rendrait l'aspect à la fois si attrayant et reposant: bref, tant que persistera l'état de choses actuel, il ne pourra trouver dans l'horticulture la rétribution qu'il convoite et le bien-être auquel il aspire.

Faire l'éducation horticole du consommateur, c'est-à-dire le renseigner sur la nature et la diversité de nos productions domestiques; lui faire connaître les noms des meilleures variétés et des endroits d'où elles viennent; lui faire comprendre que tout se tient dans le développement des forces productrices d'un pays et que lorsqu'il achète des produits de l'extérieur au détriment des nôtres, il décourage l'effort du producteur, diminue le pouvoir d'achat des campagnes, réduit l'activité commerciale et industrielle des villes et contribue ainsi à l'enchérissement du coût de la vie dont il sera tout à la fois l'auteur et la première victime; que par contre, plus il consommera de produits domestiques, plus il en fera augmenter la production et que plus celle-ci sera abondante, meilleurs seront le commerce et l'industrie et, partant, moins élevé sera le coût de la vie. C'est ainsi qu'il finira par se rendre compte du rapport d'équilibre qui existe dans l'économie d'une nation et du rôle de première importance qu'y remplit le cuisinier du sol, jusque-là considéré par lui comme le paria de la société, mais désormais, comme son bienfaiteur.

De même qu'il faut commencer par faire l'éducation physique d'un individu avant d'en faire un athlète, de même aussi faut-il commencer par faire l'éducation horticole d'un producteur, avant d'en faire un coopérateur, parce que l'éducation est cause, et la coopération, effet. Conséquemment, meilleure sera l'éducation reçue par le producteur et le consommateur, meilleure sera la coopération entre producteurs et entre ceux-ci et les consommateurs.

C'est aux techniciens qu'incombe la lourde mais combien noble et patriotique tâche de faire cette éducation et développer cet esprit de coopération indispensable au progrès de toutes les branches de la production agricole. Ils sauront s'en acquitter à l'avantage de toutes les classes et à l'honneur de leur profession, en mettant à contribution non seulement leur cerveau, leur parole, leur plume et leur ardeur, mais encore tous les précieux apports des capitalistes, des industriels et des citoyens en général. Car s'il importe de convaincre les producteurs qu'il leur faut s'unir pour devenir forts et en mesure de vendre efficacement leurs produits, il n'est pas moins important, dans bien des cas, de persuader ceux des nôtres qui disposent de capitaux qu'ils auraient tout intérêt à les investir plutôt dans des industries horticoles qui profiteront à toute la nation, que dans des entreprises étrangères parfois risquées. Jusqu'ici, leur abstention de coopérer au développement de ces industries ne s'explique pas autrement que par le défaut d'éducation en la matière. Des capitalistes et industriels ontariens ouvriront sous peu, dans nos meilleurs centres de production, de grandes fabriques de conserves alimentaires qui seront l'apanage des forces extérieures, prouvant par là qu'ils craignent beaucoup moins que les nôtres d'investir des capitaux dans l'agriculture, et qu'ils sont aussi beaucoup plus au courant qu'eux des besoins du marché de la métropole et de l'aptitude culturale de nos sols.

Descendant d'une race qui vint ici battre des sentiers, ferons-nous mentir notre sang en ne marchant plus que dans les sentiers battus?

On ne saurait trop déplorer cette absence de coopération entre le capitaliste et le producteur, et le manque de contact entre le citoyen et la terre. Puisque rien n'est contagieux pour nous comme l'exemple, sachons désormais

en tirer parti pour attirer vers elle plus de capitaux et plus de citoyens. Si tant d'hommes illustres allèrent, de tout temps, chercher à la campagne, dans la culture du jardin qui entourait leur villa, la douce quiétude qu'ils ne pouvaient trouver nulle part ailleurs, pourquoi un plus grand nombre de nos citoyens fortunés ne suivraient-ils pas cet exemple et ne goûteraient-ils pas le même charme? Tout en y reconstituant leurs forces épuisées par l'intensité du genre de vie que l'on mène aujourd'hui dans les cités devenues plus que jamais des "mangeuses d'hommes", ils pourraient se livrer soit à la culture d'un parterre, soit à celle d'un jardin potager ou mieux encore à celle d'un verger dont l'établissement constitue l'un des meilleurs placements. Que d'admirables sites la nature a échelonnés d'une façon prodigieuse, dans notre province! Que de superbes étendues de terres devraient être couvertes de pommeraies dans les comtés de Missisquoi et Huntingdon, qui sont à la province de Québec ce qu'est la vallée d'Annapolis à la Nouvelle-Ecosse!

Est-il besoin d'insister sur l'opportunité d'une intervention et d'une action gouvernementales énergiques? Tant de besoins la réclament simultanément dans les divers domaines où elle doit se multiplier, pour y satisfaire, qu'il n'est pas étonnant qu'elle ne se fasse pas toujours sentir aussi efficacement que le désireraient ceux qui travaillent à l'avancement des différentes branches de l'activité humaine.

Or, c'est précisément parce que nous sommes du nombre de ceux qui ont la vive et légitime ambition de faire atteindre à l'horticulture québécoise ce degré de développement qui s'impose pour l'amélioration des conditions matérielles et morales d'existence de l'agriculteur, que nous croyons devoir exposer ici, avec toute la respectueuse réserve qui s'impose à un fonctionnaire, les modes d'intervention gouvernementale qui nous apparaissent être présentement les plus aptes à produire ces résultats.

A venir jusqu'ici, l'action gouvernementale sans doute inspirée en cela par l'exemple d'autres pays, ne s'est pas suffisamment fait sentir, à mon sens, dans l'organisation commerciale de la production horticole, arboricole et spéciale.

Lors du congrès international d'agriculture tenu à Paris, en 1900, M. Méline reconnaissait avec sa haute autorité en la matière, que "l'agriculture a assez fait pour la production; qu'il est temps maintenant qu'elle s'occupe de la vente, et pour cela, il est indispensable qu'elle se donne l'organisation commerciale qui lui manque. Ici encore, il faut qu'elle imite l'industrie et lui emprunte ses procédés. L'industrie ne se borne pas à fabriquer de la bonne marchandise. Quand elle est créée, elle cherche à vendre dans les meilleures conditions possibles, en évitant soigneusement de se mettre entre les mains d'intermédiaires ou de spéculateurs qui lui prendraient le meilleur de ses bénéfices."

En d'autres termes, l'organisation économique de plusieurs branches de l'agriculture québécoise n'a pas évolué aussi vite que celle du commerce et de l'industrie.

En effet, ce dont nos producteurs ont le plus pressant besoin, ce ne sont pas tant des primes d'encouragement à la production que de l'éducation concernant la création de centres de production commerciale et l'or-

ganisation de la vente de leurs produits. Or, ce travail d'éducation nécessite un personnel dont l'insuffisance se fait sentir chez nous, au moment même où la pression des circonstances déclanche une avalanche de demandes d'assistance auxquelles nous sommes impuissants à répondre. Après avoir pendant quinze ans offert nos services aux producteurs pour les aider à sortir du marasme et à organiser leur production comme elle doit l'être, nous nous voyons,—maintenant que nous les avons décidés à marcher d'avant,—dans l'obligation de les leur refuser. Pour être efficace, ce travail d'éducation nécessite un personnel non seulement assez nombreux, mais encore bien entraîné et très compétent.

Un millionnaire qui, voulant commander son portrait, trouvait la somme exigée trop élevée, demanda au peintre : "Combien vous faut-il donc de temps pour faire un portrait?" "Huit jours, répondit le peintre, et quarante ans d'expérience."

Or, il arrive malheureusement bien trop souvent qu'au moment où nous devons compter davantage sur la compétence et l'expérience acquises d'un employé par ailleurs très actif et zélé, il quitte son emploi—faute de rémunération suffisante.

Ce qu'il faut, pour faire coopérer nos producteurs, se ne sont plus des sociétés dont la structure est minée par la vermoulure de la vétusté; que l'agriculture doit payer pour faire vivre, mais bien des associations coopératives locales qui feront vivre l'agriculture.

Ce qui manque présentement à nos agriculteurs, ce ne sont plus de ces pavillons d'exposition où l'on prime largement un tas de productions horticoles qui trouvent difficilement preneur à des prix rémunérateurs sur le marché, mais plutôt des entrepôts attenant aux voies de transport, où l'on puisse recevoir les marchandises achetées en commun par les producteurs de même que les produits devant y être classifiés, triés, emballés avant d'être expédiés coopérativement sur les marchés.

Pour terminer cette étude déjà longue, mentionnons quelque peu les besoins virtuels de l'horticulture ornementale et les espoirs qu'il y a lieu de fonder sur elle, pour jeter une note d'art dans la vie de l'homme des champs, pour rendre l'aspect de son habitation plus riant; pour conserver à son village un cachet d'originalité ou un facies qui cadre mieux avec ses traditions et son milieu; pour faire ressortir dans toute son éclatante beauté le "visage aimé de la patrie."

Est-il quelque chose qui puisse contribuer davantage à faire aimer le toit paternel, le clocher natal et son pays que la parure des belles végétations, c'est-à-dire du verdoyant gazon qui repose l'oeil; des touffes d'arbres et d'arbustes qui donnent l'ombrage frais, l'air pur et qui masquent les laideurs; des fleurs dont les chatoyants reflets et les parfums odorants embellissent et embaument l'existence?

Telle est l'importance du rôle de l'esthétique horticole, dans la vie des nations, qu'on la rattache intimement au progrès de la civilisation et qu'elle sert puissamment à développer, chez l'enfant, l'amour de la patrie. En effet, "le patriotisme", dit un auteur français, "est un sentiment nourri par une image; quand l'image s'efface, le sentiment perd de sa force et de sa vitalité."

"C'est donc faire à la fois une oeuvre démocratique et sociale," dit Viollet-le-Duc, "que d'ouvrir largement les sources de la beauté, de faire participer le grand nombre aux joies qu'elle engendre et d'illuminer la vie du travailleur d'un idéal."

Puis la culture ornementale contribue si puissamment à faire aimer la terre "pour sa propre beauté", il serait plus que temps de faire bénéficier toutes les classes de la société de ce luxe de l'agriculture jusqu'ici réservé pour la parure des édifices et parcs publics.

En effet, si comme le dit M. Georges de Montenach, "l'enfant doit être entouré d'arbres, de fleurs et de légumes, pour apprendre à jouir de la nature et la respecter"; si l'en veut un terme au gaspillage de nos beautés naturelles; si l'on veut, à l'instar de la Suisse "mettre tout en oeuvre pour que l'étranger, *viennne, tienne, revienne*," il est urgent que le gouvernement intervienne encore ici, non seulement pour planter le long de ses grandes artères, des cache-laideurs et des cache-misères, mais pour répandre partout dans nos campagnes et nos villages les notions d'art décoratif qui doivent présider aux plantations; pour suggérer dans la construction des habitations, des lignes architecturales qui soient plus en harmonie avec nos usages et nos conditions de milieu; pour établir, si nécessaire, à l'instar de plusieurs pays européens, des ligues ou commissions d'embellissement qui contribueront à débarrasser le pays de ces panneaux-réclame et autres laideurs défigurant nos campagnes.

"Un jour", raconte Henry Bordeaux, "mon grand-père, qui était plus riche en rêves qu'en biens de ce monde, me conduisit, petit garçon, au haut d'une montagne de notre pays de Savoie où le regard embrasse une vaste étendue de forêts, de vignes, de vallées et de monts, avec scintillant dans sa coupe verte, un lac glorieux et doux. Il me fit admirer et reconnaître les bornes lointaines de ce paysage, au-dessus duquel le ciel se penchait avec des sourires de rayons. Puis, après un silence, tournant vers moi sa tête chenue, il me dit avec un accent généreux: "Tout cela, je te le donne". Je ne compris guère alors l'importance de ce legs d'un vieillard aux yeux déjà tournés vers l'au delà. Mais il m'en souvient aujourd'hui et j'en remercie le cher aïeul disparu: il m'a donné une chose qui était vraiment sienne, une chose qu'il avait possédée toute sa vie et que nos ancêtres s'étaient religieusement transmise, une chose dont le prix lui paraissait plus estimable à cette heure où, cependant, de plus radieux et vastes paysages étaient près de s'ouvrir devant lui: il m'a donné la vision de notre beau pays natal."

## CONCERNING THE C.S.T.A.

### NOTES AND NEWS

J. E. Bowstead (Wisconsin '20), Associate Professor of Animal Husbandry at the University of Alberta, has received the Ph.D. degree from the University of Wisconsin.

J. E. McIntyre (Toronto '21), Maritime Representative of the N. V. Potash Export My., has changed his mailing address to 185 King Street, Moncton, N. B.

L. A. Hietanen (Toronto '27) is teaching at the Smiths Falls Collegiate. His mailing address is Box 254, Smiths Falls, Ont.

A. Fraser Ross, (Toronto '22) who has been Poultry Food Specialist for the Maple Leaf Milling Company in Montreal for the past two years is now attached to the staff of that Company at West Toronto, Ont.

J. M. Brown (Toronto '14), Associate Professor of Animal Husbandry at the Manitoba Agricultural College, is taking graduate work at the University of Minnesota. Until the end of March, 1930, his address will be Department of Animal Husbandry, University Farm, St. Paul, Minn., U.S.A.

A. F. Barss (Cornell '12), Professor of Horticulture at the University of British Columbia, has received the Ph.D. degree from the University of Chicago.

G. F. H. Buckley (Alberta '20), formerly Assistant Professor of Field Husbandry at the University of Alberta, has been appointed Agrostologist at the Dominion Experimental Farm, Brandon, Man.

H. B. Boyd (Saskatchewan '23) has received the appointment of Assistant Agricultural Economist at the Connecticut Agricultural Experiment Station, Storrs, Conn., U.S.A., and will be engaged in research work in cigar leaf tobacco.

L. T. Wilson (Saskatchewan '24) who is taking graduate work at the University of Wisconsin has changed his mailing address to 726 University Avenue, Madison, Wis., U.S.A.

R. H. Thexton (Manitoba '23), Assistant in Bacteriology at the Manitoba Agricultural College, is taking graduate work in agricultural bacteriology at the University of Wisconsin. His mailing address is 810 Oakland Avenue, Madison, Wis., U.S.A.

A. McTaggart (Toronto '12), for the past seven years Assistant Professor of Agronomy at Macdonald College, has accepted the appointment of Senior Plant Introduction Officer, Council of Scientific and Industrial Research, with headquarters first at the Waite Institute, University of Adelaide, and later on at Canberra, Australia.

### APPLICATIONS FOR MEMBERSHIP

The following applications for regular membership have been received since September 1, 1929:—

Denike, G. N. (Manitoba, 1929, B.S.A.) Swift Current, Sask.

Shirriff, C. (Manitoba, 1929, B.S.A.) Regina, Sask.

Strachan, B.B. (Manitoba, 1929, B.S.A.) Brandon, Man.

Taylor, C. F. (McGill, 1929, B.S.A.) Ithaca, N.Y., U.S.A.

## INTERNATIONAL SOIL CONGRESS

The International Soil Congress will take place from June 1st to June 11th, 1930, partly in Moscow and partly in Leningrad. From June 11th to 27th there will be the main excursion including a trip down the Volga, Causasus, the Ukraine, and so on. Special excursions will be arranged for those interested in visiting Crimea, Siberia and Central Asia. Participation is open to all members of the International Society of Soil Science. The programme of the Congress embraces not only soil science and agronomy, but also geography, geology, climatology, culture of technical crops, road building, etc.

The American Society for Cultural Relations with Russia is organizing the delegation, as it has other delegations. A general Committee will be appointed of representatives from every State Agricultural College or Station. Any persons who might be interested in attending the Soil Congress are requested to communicate with this Society at 22 East 55th St., New York City.

## VACANCIES IN INDIA

The Government of India is inviting applications for the following appointments:—

1. *Expert in Animal Husbandry.*

Candidates should be leading authorities on either livestock breeding, animal nutrition or veterinary science and should have a wide general knowledge of the other two of these subjects. Oriental experience is desirable but not essential. Pay, Rs. 2500 (approximately \$910.00) per month, with an increase of Rs. 125 per month during second year, and a similar increase during third year, up to a maximum of Rs. 2750 (approximately \$1,000) per month, plus overseas allowance of £13 : 6 : 8d (approximately \$64.75) per month. Appointment is for five years in the first instance and is non-pensionable, but the officer will contribute one-twelfth of his monthly pay to a special provident fund, to which Government adds 75% of subscription and interest. Leave on full average pay up to one-eleventh of period spent on duty, with additional providing for leave on medical certificate. Free first class passage to India will be provided. Applications, which should give full particulars of qualifications and experience, age and birth place, and include the names of two or three references, should be submitted before 30th November, 1929, to the Under Secretary of State, Economic and Overseas Department, India Office, Whitehall, London, S.W. 1, England.

2. *Director, Agricultural Research Institute, Pusa.*

Candidates should possess high administrative ability and considerable experience in agricultural research. Oriental experience is desirable but not essential. Terms of appointment and particulars regarding applications are the same as for the Expert in Animal Husbandry (see above).

## EXPANSION OF CANADIAN LABORATORY SUPPLIES, LTD.

Canadian Laboratory Supplies, Ltd., Toronto, has recently been incorporated on a Dominion basis and has taken over the laboratory supply business of Lymans Limited of Montreal. The result is the amalgamation of two distinctly Canadian concerns (Canadian Laboratory Supplies Ltd., established in 1918 and Lymans Limited established in 1800) into one organization with offices in Montreal and Toronto. A new catalogue is in course of preparation.

The name of Canadian Laboratory Supplies, Limited, is being retained by the new organization.

## AN ANNIVERSARY

It is worth recording that on the evening of October 9, 1919—just ten years ago—the committee appointed to consider the organization of the C.S.T.A. held its first meeting at Ottawa. Between that date and the Organizing Convention in June, 1920, this committee held thirty-four meetings, the minutes of which are now on file in the Society's headquarters. Of the 411 charter members who joined the Society during this period of organization, the names of 243 have remained continuously on the membership list until the present time.

The development of the C.S.T.A. since June, 1920, is quite an interesting story, and perhaps it would be fitting, after the tenth annual meeting next June, to put the story into permanent form, so that all members might know more about the early history of their society. The matter should at least be given some consideration.

As it exists today, the C.S.T.A. compares favourably with any other professional organization in Canada. Its membership has reached 1,100, its journal is firmly established, its local branches extend from coast to coast. Increasing recognition is being given to the Society, resulting in the donation of its present headquarters, of scholarships, of various grants, etc. Its conventions and its standing committees are contributing much towards agricultural education and research.

What may the next ten years bring forth?

## GRADUATE FACILITIES IN AGRICULTURE IN CANADA

During the early part of 1929 Dr. Robert Newton of the University of Alberta completed a survey of the graduate facilities in agriculture in Canada. A draft of his report was presented at the annual convention of the C.S.T.A. in June at Winnipeg. The complete report has now been printed and will be mailed to every member of the Society early in October. The survey, as well as the printing and distribution of the report, were financed by the International Education Board of New York.